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PROGRESS REPORT

ENVIRONMENTAL PROGRAMS

- 1984 -

WHITE RIVER SHALE PROJECT
FEDERAL PROTOTYPE OIL SHALE TRACTS Ua AND Ub

White River Shale Oil Corporation
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July, 1985

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the "1984 Progress Report Environmental Program White River Shale Project" is to present the results of the continuing environmental monitoring and reclamation activities associated with the development of Federal Prototype Oil Shale Lease Tracts Ua and Ub located in northeastern Utah. This report includes monitoring studies conducted during the calendar year 1984, with the exception of the water resources section (6.0) which is based on the 1984 water year (i.e. October 1, 1983 through September 30, 1984).

This was the tenth consecutive year of environmental investigations conducted for the White River Shale Project (WRSP). Environmental baseline conditions have been delineated as the range of values noted between program initiation in late 1974 and the end of the 1984 monitoring year. This monitoring program is also providing data for assessment of potential impacts due to development on the tracts. 1984 represents the third year of construction-related activities.

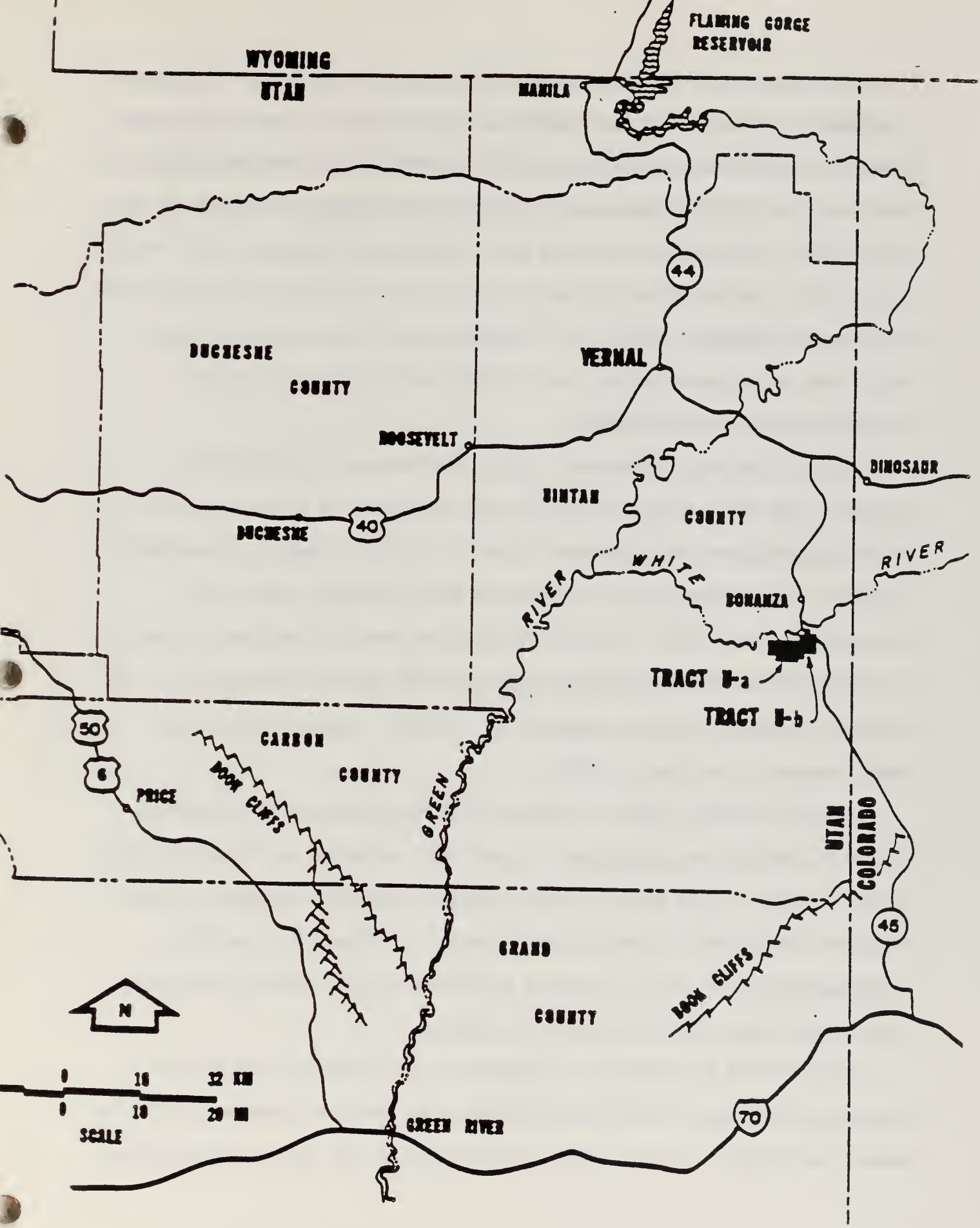
1.2 BACKGROUND

The White River Shale Project (WRSP) was established in 1974 to plan for and implement the joint development of Tracts Ua and Ub. Each tract encompasses 5120 acres of federal land. Figure 1.2-1 shows the location of the leased lands. The lease to Tract Ua is held equally by Phillips Petroleum Company and Sun Shale Oil Company. The lease to Tract Ub is held by Sohio Shale Oil Company.

The White River Shale Oil Corporation (WRSOC), in its agency relationship to the lessees of Tracts Ua and Ub, has been retained to manage development of the WRSP. Thus, the WRSOC is responsible for implementation of environmental monitoring requirements mandated by the oil shale leases. Environmental monitoring programs for the WRSP are conducted by independent environmental consulting firms under contract to the WRSOC.

Since work under the leases began in 1974, four significant environmentally oriented tasks have been completed for the WRSP. First, the "Detailed Development Plan" (DDP), required by lease provision was submitted to the Department of Interior - Oil Shale Office in June, 1976 and subsequently revised, updated, and resubmitted in July 1984. This plan describes the schedule, activities, and expected results associated with planning, construction, operation and abandonment of a commercial oil shale processing facility on Tracts Ua and Ub. The DDP was approved in March, 1982 following the lifting of a court-imposed injunction which had suspended tract development since May, 1977.

Secondly, the lease-required two-year environmental monitoring and data collection program was completed for the WRSP in January, 1977. Results of



PROJECT LOCATION MAP
TRACTS U-a & U-b

FIGURE
1.2-1

this study were published in October, 1977 as the "Final Environmental Baseline Report." Annual "Progress Reports," such as this document, have been prepared in subsequent years (1977-1982) to present data from the WRSP's continuous monitoring program which update environmental conditions on the lease tracts. Monitoring continued during the period from May, 1977 through March, 1982 in order to verify observations made during the Baseline period, evaluate environmental trends on a long-term basis, track ambient ozone levels over an extended period, and evaluate more refined biological resources monitoring techniques.

Thirdly, the WRSP conducted a study from November, 1974 through December, 1978 to develop a technology for revegetating disturbed sites and reclaiming processed shale disposal areas. The final report, "Revegetation Studies for Disturbed Areas and Processed Shale Disposal Sites," was published in June, 1979. The WRSP reclamation research program has continued and the annual progress reports have provided updated information on the results of research studies supported by the WRSP. Section 7.0 of this report updates this area for 1984.

Fourth, in June, 1982, the "White River Shale Project Environmental Monitoring Manual" was developed to establish a detailed environmental monitoring program for the WRSP to track potential impacts of project development, and the success of mitigation measures. Information from these investigations will provide feedback to design and operations to minimize and/or correct any identified adverse effects.

Construction is currently in progress at the WRSP and monitoring is proceeding according to the plan established by the Environmental Monitoring Manual, as revised. Construction activity at the site during 1984 included

construction of the Hoist House and Decline Exhaust Fan, and placement of riprap on the banks of the White River. Substantial topsoil-like material has been stockpiled for use in future reclamation activities and revegetation of certain disturbed areas on tracts have been initiated.

1.3 SUMMARY OF RESULTS

Environmental conditions within or adjacent to the WRSP have been continuously monitored since 1974. During 1984, monitoring programs were conducted in air resources, vegetation resources, aquatic biology, terrestrial fauna, water resources, and reclamation research. Integration of project information of all disciplines into the Ecosystem Analysis data library and management system was also continued.

A main objective of the 1984 monitoring program was to continue investigation of tract development related impacts. The following is a summary of the results of the 1984 investigations.

Monitoring at five meteorology sites, two air quality sites, and five sound level sites was conducted in 1984. Air quality and meteorology equipment were removed at the end of 1984, per the approved 1985 Environmental Monitoring Plan. Ozone and particulates were found in the highest quantities (approaching 70% and 25%, respectively of their short-term NAAQS). Other major pollutants (CO, SO_2 and NO_2) were found at values less than or equal to 10% of their applicable NAAQS. These concentrations were similar to those found in previous years. It is likely that the high ozone levels recorded during 1984 were not produced locally and were therefore not caused by tract construction activities.

Lower than normal temperatures, wind speeds, and net thermal radiation and high relative humidity values were recorded during 1984. Due to tropical air masses in the area, summer wind speeds were also lower and greater relative humidities were found in the tracts.

The 1984 water year was the third consecutive year above average precipitation. The tract average of 14.78 inches was the highest annual average exhibited for the 10 years of continuous monitoring. Annual precipitation for 1984 ranged from 13.71 inches at RS-11, to 16.82 inches at RA-4. Spring precipitation compared to the six year seasonal mean was 230% above normal. Summer and fall values were moderately above normal with increases of 34% and 14%, respectively. Winter precipitation was 1.2% below normal precipitation.

Two significant rainfall events were recorded on February 14 and June 6-7, 1984. A 24-hour event recorded on June 7 at Plant Site Wash matched the previous tract maximum. Pan evaporation at Plant Site Wash (EVP-1) was higher than previous measurements at 35.61 inches, and at Southam Canyon (EVP-9) was recorded at 22.43 inches. EVP-1 consistently reported greater evaporation rates.

Mean annual runoff for White River station 6700 of 1344 cfs was the second highest in the 61 years of record. As in 1983, high flows in the White River were due to heavy snowpack in the mountains. Water quality and suspended solids data collected in 1984 were generally within the range of baseline values except for several parameters exceeding baseline maximums in April due to lower basin runoff and high values for suspended solids and biochemical oxygen demand (BOD) in June due to upper basin runoff.

Mean annual runoff at Evacuation Creek Station 6430 was greatest for the 10-year period of record. This was due to heavy snowpack and several intense summer thunderstorms. Water quality data collected in 1984 for Evacuation Creek was similar to baseline values. Runoff at Southam Canyon Station 6610 and Asphalt Wash Station 6625 was lower than the 9-year mean

annual runoff. This is likely due to several significant storm events not being recorded. The Plant Site Wash Station 6602 recorded one runoff event in 1984. No water quality data were collected at this station in 1984.

In 1984, a monitoring program was developed for the Retention Dam Pond (RES-1) to determine its volume and water quality, and also to estimate any subsurface leakage from the pond. Volume of the pond ranged from 1.9 acre-feet in May to 3.70 acre-feet in July. Total capacity of the pond is 230 acre-feet, consequently current volumes are ranging only 1-2 percent capacity. Specific conductance ranged from 3130 micromhos to 4720 micromhos. Although water quality data indicated that the reservoir was similar to ground water from the Birds Nest Zone, concentrations of several organic constituents including total phenols, dissolved organic carbon, and nitrite plus nitrate were higher than those of natural tract waters. This was most likely caused by the organic-based grouting material used in sealing the Birds Nest Zone in the mine shaft and decline. Concentrations of these organic compounds are expected to have returned to normal, as the sealing process was conducted only one time.

The 1984 groundwater levels in the Birds Nest Zone were generally within the range of baseline conditions. Some recovery of wells P-2 Lower, G-11, G-15, and G-21 was exhibited. Water quality of the wells appears to be unchanged from baseline conditions with the exception of increases in manganese to levels above baseline conditions. This may be due to contamination from the well casing.

The vegetation monitoring program was composed of seven interrelated tasks designed to document existing conditions, determine and quantify interaction between vegetation and abiotic and biotic factors, and potential

impacts on vegetation due to development. Production of annual plant biomass for 1984 was low with the total of all four community types averaging only 25.2 g/m^2, compared to 64.6 g/m^2 in 1983. Production and annual cover values ranged from 0.5 g/m^2 and 0.2% for the juniper types, to 70.5 g/m^2 and 21.3% in riparian areas.

Mean sagebrush leader growth for 1984 (7.6 cm) was the second highest value recorded during the ten years of study. Comparison of the study sites on tract showed Site 3 had the longest stem lengths, and Site 5 had the shortest.

Litterfall measurements during 1984 was the highest for shadscale, at 316.6^2 g/m^3, and the lowest for rabbitbrush at 39.4 g/m^3. Juniper litterfall was greater in 1984 (225 g/m^2) than in 1981-1983 (123 g/m^2, 112 g/m^2, and 54 g/m respectively). Animal use of shrubs assessed using the Cole Browse Survey showed greasewood leader growth was browsed (71%) more than sagebrush (42%) and shadscale (6%).

Lichen monitoring was continued at 21 permanent stands located along three transects radiating from the proposed plant site. The 1984 lichen monitoring program completed the baseline characterization of the saxicolous lichen communities at the 21 stands. The frequency of most of the prevalent species (two were slightly higher, and two were slightly lower) did not change significantly from year to year.

Soil moisture content ranged from 24.3% in January to 6.9% in July. Moisture levels were 1-2% higher in surface soils during the summer, and 5-10% higher during the winter. The pH levels showed a sharp increase in April. Soil bacteria fluctuated in an annual cycle characterized by a winter-spring high and a summer low, although bacterial counts through the

year were more evenly dispersed than in previous years, most likely due to above normal summer precipitation.

Areas reseeded in 1982 and 1983 were sampled in the spring and fall of 1984. For the 1982 reseeded areas, average density of all plots on all sites decreased from 9.6 plants/m^2 in the fall of 1983 to 7.4 plants/m^2 in the fall of 1984. Based on the percentage of one-square foot plots containing one or more seeded plants, the success rating by the fall of 1984 was: six of the 12 plots in the excellent category (Vallentine 1974) (750%); one in the good category (40-50%); and five in the poor category (10-25%). The most common species were western wheatgrass (4.9 plants/m^2), sagebrush (1.2 plants/m^2), and Indian ricegrass (0.3 plants/m^2).

Seventeen revegetation monitoring sites located in 1983 reseeded areas were sampled in the spring and fall of 1984. Average density of all plots on all sites increased from 18.2 plants/m^2 in June to 29.4 plants/m^2 in October. In the fall of 1984, nine of the 17 plots were considered to be in the excellent category, 4 in the fair, and 4 in the poor categories. The most common species in the fall of 1984 were western wheatgrass (9.6 plants/m^2) and Indian ricegrass (8.8 plants/m^2). Sagebrush, fourwing saltbush, and shadscale densities decreased from the spring of 1984 to the fall.

Flows and total suspended solids in the White River were higher for 1984 than the previous three years, resulting in high scouring action and reduced light penetration. This information further identifies the White River as a light/substrate limited system in which algal and benthic production levels were lower during high flow periods.

Three major groups were monitored for the terrestrial fauna program, including foliage invertebrates, birds, and mammals. Reptiles were not systematically studied during 1984.

Foliage invertebrate abundance, biomass, and richness increased on all host plants from 1982 to 1984. These increases are most likely related to increased precipitation for the same time period. Mean foliage invertebrate abundance, biomass, and richness of big sagebrush along different transects were positively correlated with leaf water potential. The same faunal characteristics and leaf water potential were negatively correlated with ground slope.

Bird species richness of 70 species and composition in all habitat types for 1984 were similar to those observed in 1982 to 1983. Distribution of species, and biomass among trophic groups and guilds changed from 1983 to 1984. This shift is consistent with results of the baseline study that the structure of the avian community varies over time.

Waterfowl abundance and raptor reproductive success were lower during 1984. The decrease in raptor reproductive success is most likely due to the decline of the desert cottontail population, an important prey species. A greater number of bald eagles (22 individuals) were located in 1984 than in either 1982 or 1983. The abundance of bald eagles over the winter is probably tied to the availability of food items as controlled by snow accumulations, ice along the river, and prey population levels.

Rodent communities on Juniper and Riparian study sites decreased from 1982 to 1984, most likely due to the harsh winter of 1983 to 1984, and a flash flood during August, 1982. The desert cottontail population declined significantly from 2 to 3 ind/ha in August 1983 to 0 to 0.15 ind/ha in the

spring of 1984. Mule deer abundance values in 1984 of .20 deer/km were intermediate to those of 1982 (0.11 deer/km) and 1983 (0.24 deer/km).

Reclamation research conducted in 1984 was continued at the Anvil Points, Colorado and WRSP Section 6 study sites. Measurements taken to monitor migration of salts in soil trenches showed that surface topsoil was higher than other topsoil samples for pH, but was not significantly different from the surface shale sample. Other topsoil samples had lower pH and EC values than the shale samples. The 1984 data showed a drop in pH to roughly 1982 levels.

As of June 1984, percentage survival of the species used in trench plantings, basin plantings, and flat plantings were: fourwing saltbrush 96%; shadscale 58%, cuneate saltbush 81%; western wheatgrass 92%; greasewood 100% prostrate kochia 60%; and seepwood from trench plantings only, 29%. Both plant heights and cover values were higher in 1983 indicating growth had continued.

In the topsoil Stockpile Study where a control, two different seed mixes, and fertilizer regimes were investigated, shallow rooted plants were found to have the highest average density of 24 plants/m^2, whereas the deep rooted mix averaged 15 plants/m^2 and nonseeded areas averaged 5 plants/m^2. There was no difference due to fertilizer. Results for the topsoil samples also showed difference in moisture and respiration, in which the control sites were lower than the treatment sites.

In October 1983, two areas, one with substantial annual plant cover, and one with less than 5% cover were seeded with a standard shrub/grass mix using drill and broadcast techniques for application. By the fall of 1984,

very few plants were observed in the entire area and none were found in the broadcasted plots.

Transplants of big sagebrush, fourwing saltbrush, shadscale, and rubber rabbitbrush were also planted in both areas of high and low annual plant cover. By October 1984, the treated site averaged 61% total survival, and the untreated site averaged 3% total survival. The cause of mortality was primarily due to browsing by rodents and rabbits.

A sensitivity study of vascular plants including sagebrush, rabbitbrush, fourwing saltbush, Utah juniper and Lecanora peltata, a foliage saxicolous lichen species, to five different levels of SO_2 showed that L. peltata showed sensitivity after exposure to 4 ppm. Exposure of four vascular plants to ranges of SO_2 from 0.5 ppm SO_2 to 4 ppm for a 48 hour period showed that significant visual damage, decreases in leaf chlorophyll content, and decreases in transpiration and photosynthesis occurred in sagebrush, rabbitbrush, and Utah juniper. These three species were also sensitive to exposure of 0.4 ppm for SO_4 for 30 days. Fourwing saltbush showed no effects to SO_2 after 48 hours. The 24 hour primary standard for SO_2 (NAAQS) is 0.14 ppm, which is considerably below the test levels used in these experiments.

It was also determined that the chlorophyll a/b ratio and amount of chlorophyll a/gm leaf material on a wet weight basis were the most sensitive techniques for measuring the response of the vascular plants to SO_2. Sagebrush and rabbitbrush were found to be the most sensitive species. Sagebrush has been chosen as the key vascular plant species to monitor on the tracts because of its sensitivity to SO_2, low palatibility, and abundance on the tracts.

Data collected in 1983 for all of the diciplines were placed on computer tapes and sent to ERI for inclusion in the data management system in Logan, Utah. Procedures for logging in, cataloguing, and storing the data were developed. This system contains information on the type of data collected, sampling dates, frequency of data collection, sample site location, and the consultant responsible for data collection.

Data files for all disciplines from 1974 through 1983 were catalogued and stored in the library. Two computer tapes with this information were submitted to WRSOC in December, 1984.

Four computer programs were developed for use in conjunction with the data library. These included two programs used to copy data files from tape to computer and vice versa; a third program, LIBRARY, concerning the data base, and a fourth program, MONITOR for identifying relationship changes for various parameters used to monitor oil shale development.

Evaluation of ecological relationships that may be useful in monitoring potential environmental effects due to oil shale development initiated production of two documents for WRSOC in 1984, "WRSP Environmental Monitoring Program Considerations" and Guidelines for WRSP Environmental Monitoring Program Redirection."

Because of the reduced effort in development by WRSOC the role of pathway identification in 1984 was changed from redirecting full-scale monitoring of sensitive areas to reduction in monitoring to a minimum level.

Chapter 2.0

2.0 AIR RESOURCES

2.0 AIR RESOURCES

2.1 INTRODUCTION

The air quality on Tracts Ua and Ub has been monitored continuously by AeroVironment Inc. under contract to WRSOC since data collection began in 1974. At the beginning of the air monitoring program, an extensive measurement network was established. This network included eight stations measuring both air quality and meteorology and four others with only meteorology. Four of these 12 stations were located on the tracts, with the other eight surrounding the tracts up to two miles away. This intensive siting gave a thorough definition of the air quality on site, and the quality of air being transported in and out of the tract boundaries.

The first full year (1975) of air quality monitoring showed that the air over the tracts was quite homogenous. Therefore, in May 1976, the number of stations was reduced to one combination air quality and meteorology site (A6) and three auxiliary meteorology stations (the existing sites at A4 and A11 and a new site at A13). The stations remained unchanged until 1982.

In the summer of 1982, construction activities including site preparation, mine development and road improvements were started. This activity dictated changes in the monitoring program in accordance with the Environmental Monitoring Manual. Air quality impacts, especially dust related disturbances, were expected during construction. To measure these impacts, monitoring of TSP and wind was initiated at station A10.

This station was chosen as being representative of the area with maximum impacts during drainage conditions (a situation of high pollution potential).

It was important to maintain monitoring of the background air quality concurrent with monitoring of potential impacts. This task had previously been accomplished at station A6, but construction activities very close to this station were biasing the data. Therefore, the background air quality measurements were transferred in mid-1982 to station A4, a site further away and not downwind from the activity. In the following sections of the report, it should be noted that the analysis of background particulate air quality switches from A6 to A4 in April 1982, and background gaseous air quality in July 1982. A statistical analysis of three months of overlapping ozone data at both sites in the 1982 annual report showed strong correlation of the data at both sites, which supported the hypothesis that the background air quality should be the same for the whole area. Meteorological measurements were continued at A6, since meteorology is not affected by construction.

Monitoring continued at the five sites as described through 1983 and 1984. There were only minor changes to the monitoring program in 1984. The largest change in the program occurred after the end of the year (1984) when all WRSP air quality and meteorology monitoring was discontinued. As described in the EMM, the monitoring program is designed to detect project "impacts," of which none are expected during the planned construction suspension period. Air quality moni-

toring will recommence when air impacts due to construction or operation are likely.

The monitoring program and data collected in the years 1974 through 1983 are described and summarized in other reports (White River Shale Project Reports, 1976 through 1984; Detailed Development Plan, 1981; and PSD Permit Application, 1981). This section describes the monitoring program in 1984. It discusses the data collected during the year and relates these data to comparable data for the baseline period (1975 through 1981 when no construction activities occurred on the tracts).

2.2 SUMMARY

During 1984, monitoring continued at the five meteorology and two air quality sites. Sound levels were measured at five sites (a reduction of one from 1983) for the first six months only. All air quality and meteorology equipment were removed at the end of the year. Problems encountered during the year's data collection were mostly weather related (i.e., TSP sites not accessible, radiometer bulb covered with snow and later cracked) or because broken equipment was not replaced as the program came to a close (i.e., A6 20 m wind and σ_θ chart recorder back-up).

Air quality concentrations measured in 1984 were similar to those of previous years. Ozone and particulates were present in the highest quantities, approaching 70% and 25% of their respective short-term NAAQS. All other major pollutants (CO, SO_2, and NO_2) were present at values less than or equal to 10% of their applicable NAAQS for all averaging times. Ozone was present in slightly higher than normal quantities, especially in the winter, and particulates were much lower than previous years. Other pollutant measurements were quite low as usual. Since it is unlikely that the ozone was produced locally, it is probable that the construction activities on the tracts in 1984 did not adversely impact the local air quality.

Meteorologically, 1984 was less normal. Major pressure systems that govern the weather pattern were stronger and/or "out of location," leading to unusual conditions. The winter (especially January and February) had extremely cold temperatures, low wind speeds, high relative

humidity, and low net thermal radiation, and was generally foggy and stagnant. The summer weather was closer to normal patterns, but was still generally more humid and less windy due to a greater frequency of tropical air masses being drawn into the area. This type of air mass also leads to a greater frequency of thundershowers.

The air quality and meteorology are closely connected, although the complexity of the relationship makes exact cause/effect predictions difficult. For example, the greater moisture and low wind speeds may have mitigated dust impacts from the construction activities. Also, the stagnant conditions in the winter may have allowed pollutants produced elsewhere to build up the ozone levels over the tracts.

2.3 PROGRAM DESCRIPTION

2.3.1 Objectives

The initial objectives of the air monitoring program were:

- To characterize the air quality environment in the vicinity of the tracts in sufficient detail to provide a complete description of the baseline situation against which future air quality could be compared.
- To describe the meteorological environment in the vicinity of the tracts in sufficient detail to provide input data for modeling to simulate the dispersion of air pollutants that would be generated by future developments on the tracts.

Additionally, due to legal complications which delayed the start of construction until mid-1982, a third objective was added:

- To determine the year-to-year variation in the baseline air quality and meteorology of the area in order to see whether the initial two years of measurements adequately represented the ambient conditions.

During the construction activities on Tracts Ua and Ub from 1982 through 1984, changes in the ambient levels of particulates and gaseous pollutants were possible. Thus, the air resources monitoring program took on other objectives:

- To quantify the air quality impacts of various levels of oil shale development on Tracts Ua and Ub.
- To demonstrate that impacts of the air contaminants emitted by the facilities are in compliance with the National Ambient

Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as well as with Utah air quality standards.

- To identify areas where additional control of air contaminant emissions would be appropriate or necessary.
- To continue observing the evolution of regional air quality.
- To continue monitoring the meteorological environment to provide additional data for future modeling efforts as well as to monitor meteorological events (such as frontal passages) that might affect the regional air quality.

These objectives were outlined and discussed further in the EMM and are designed to be flexible in meeting the needs of the overall WRSP environmental program as the project progresses through various stages of development.

2.3.2 Air Quality Monitoring Program

During 1984, gaseous air quality was measured at one site and particulates at two. The site locations and parameters measured at each of the sites are shown in Figure 2.3-1. All parameters shown were monitored for the full year.

Table 2.3-1 lists the instruments used to monitor the air quality parameters during 1984. All instruments comply with EPA regulations. This table also gives the lower detection limits, data precisions and lower validity limits of all the instruments. All parameters, except total suspended particulates, were monitored continuously. Data were recorded in one-minute averages on cassette tapes and on multipoint

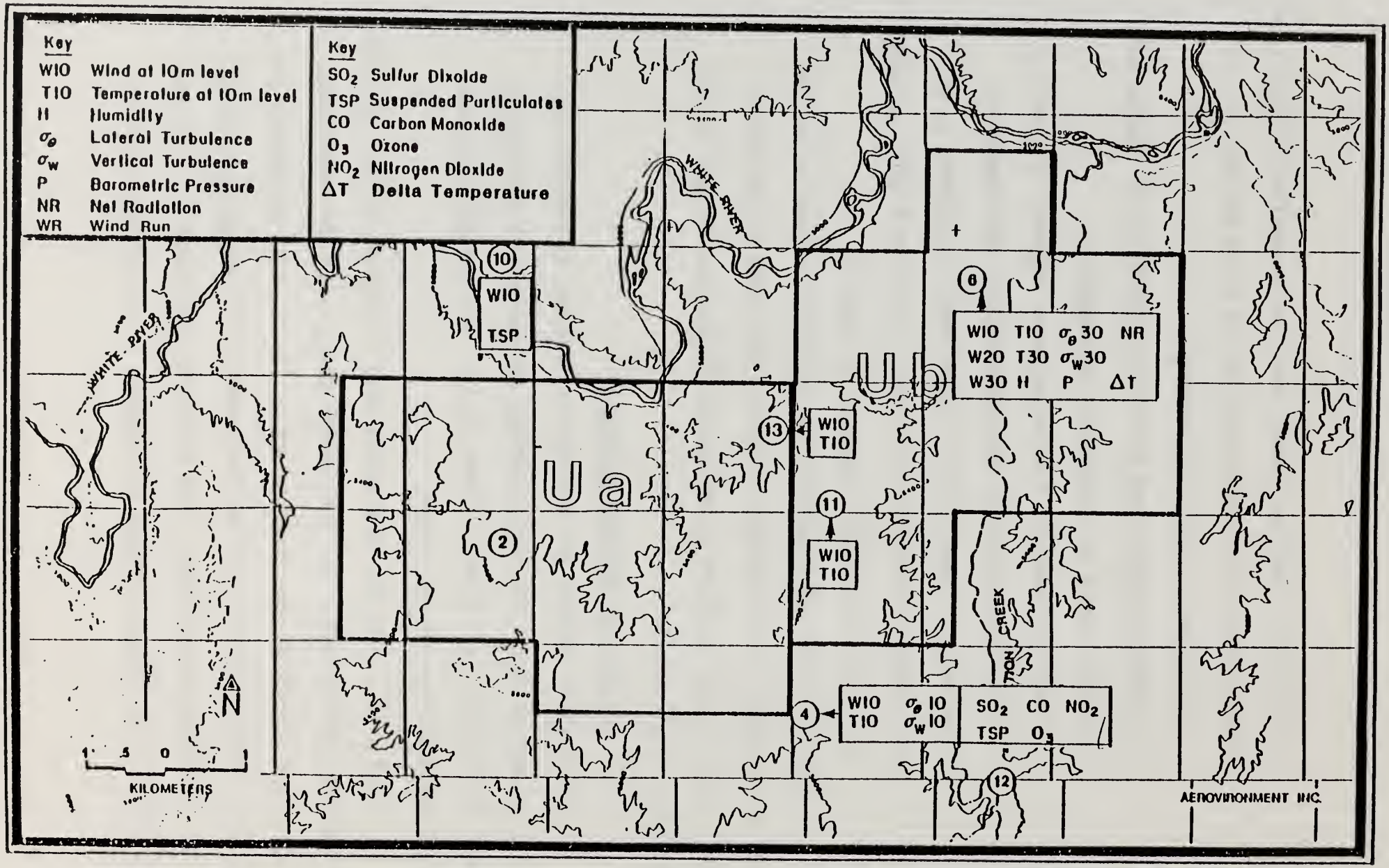


FIGURE 2.3-1. Locations of meteorological and air quality measurement stations on Tracts Ua and Ub during 1984.

TABLE 2.3-1. Air quality monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1984.

Parameter	Monitoring Instrument	Instrument Lower Dectection Limit	Data Precision	Lower Limit of Data Validity
O_3	Monitor Labs Model 8410E ozone analyzer, chemiluminescence	2 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
CO	Monitor Labs Model 8310 infrared	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
NO_x	Monitor Labs Model 8440E NO/NO_x analyzer, chemiluminescence	5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
NO		5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
$NO_2(NO_x-NO)$		5 $\mu g/m^3$	12 $\mu g/m^3$	12 $\mu g/m^3$
SO_2	Thermo Electron Corp. Model 43 pulsed fluorescent SO_2 analyzer	25 $\mu g/m^3$	8 $\mu g/m^3$	25 $\mu g/m^3$
TSP	Sierra Instruments Model GMWC-2000H, Hi-Vol with constant flow	0.5 $\mu g/m^3$	± 6% of Toad or 1 $\mu g/m^3$	1 $\mu g/m^3$

strip charts every two minutes. Total suspended particulates were measured every third day. Additionally, a collocated sampler at Site A4 took samples every sixth day.

The percentage of time each air quality parameter was monitored on Tracts Ua and Ub in 1984 is presented in Table 2.3-2. For TSP, the calculation was based on the designated TSP samplers and not the collocated sampler. TSP was the only parameter which fell below 90% data capture (80% is required for PSD programs). This was mostly due to the severe weather in January and February which limited accessibility to the sites, especially A10. Also, some of the filters collected were damaged by water in the weighing lab.

2.3.3 Meteorological Monitoring Program

Figure 2-3.1 also showed the five sites where meteorological data were collected and Table 2.3-3 lists the meteorological monitoring equipment used. Meteorological data were collected continuously and recorded on cassette tapes. Strip charts are also used at Sites A4, A6 and A10 for backup records.

Table 2.3-4 lists the percentages of data recovered for each meteorological parameter monitored on the tracts. Those which fell below 90% include:

- 20 m wind speed at A6 -- the wind speed sensor at the 20 m level was removed from operation due to continuous malfunctioning. It was not replaced.
- Net thermal radiation at A6 -- the net radiometer sensor bulb was cracked and full of water on a couple of occasions

TABLE 2.3-2. Percentage of time air quality parameters were monitored during January 1 - December 31, 1984.

Station	Component	Percentage of Time Monitored in 1984
A4	SO_2	96
	NO_2	95
	O_3	95
	CO	96
	TSP	81
A10	TSP	75

TABLE 2.3-3. Meteorological monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1984.

Parameter	Monitoring Equipment	Instrument Lower Detection Limit	Data Precision	Lower Limit of Data Validity
Wind Speed	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6, 10)	1 m/s	0.2 m/s	1 m/s
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	1 m/s	0.2 m/s	1 m/s
Wind Direction	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6, 10)	N/A	5%	N/A
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	N/A	5°	N/A
Temperature	Meteorology Research Inc. Model 840 thermistor (Sites 4, 6)	$-30^{o}C$	$0.5^{o}C$	$-30^{o}C$
	Meteorology Research Inc. Model 1071 thermistor (Sites 11, 13)	$-34^{o}C$	1°	$-34^{o}C$
Delta Temperature	Meteorology Research Inc. Model 840 thermistor	N/A	$0.2^{o}C$	1°
Sigma Theta	Meteorology Research Inc. Model 1022 with sigma processor	0.5^{o}	1°	N/A
Sigma W	R.M. Young Model 27100, with AV sigma processor	0.05 m/s	0.05 m/s	0.05 m/s
Barometric Pressure	Science Associates No. 370	600 mm Hg	0.5 mm Hg	600 mm Hg
Net Thermal Radiation	Fritschen net radiometer	-0.40 Ly/min	0.05 Ly/min	-0.40 Ly/min
Relative Humidity	WeatherMeasure Inc. H321-S	0%	5%	5%

TABLE 2.3-4. Percentage of data recovered for meteorological parameters during January 1 - December 31, 1984.

Station	Component	Percentage of Time Monitored in 1984
A4	Wind (10 m)	98
	Temperature (10 m)	96
	Sigma theta (10 m)	97
	Sigma w (10 m)	98
A6	Wind (10 m)	95
	Wind (20 m)	43
	Wind (30 m)	99
	Temperature (10 m)	100
	ΔTemperature (30-10 m)	100
	Relative Humidity	81
	Sigma theta (30 m)	82
	Sigma w (30 m)	67
	Net thermal radiation	52
	Barometric pressure	100
A10	Wind (10 m)	92
A11	Wind (10 m)	96
	Temperature (10 m)	96
A13	Wind (10 m)	100
	Temperature (10 m)	100

for several days. The sensor was sent to the manufacturer for repair.

- Sigma w at A6 -- the σ_w processor received full scale signals when the wind speed cups were not moving, invalidating some of the data. The σ_w sensor was also discovered to be full of water on one occasion making it necessary to remove the sensor for several days until it dried out. The wiring also developed a short which took a couple of days to track down.
- Sigma theta at A6 -- it was discovered that whenever the wind direction changed ranges, σ_θ always went full scale. In order to preserve the strip chart recorder and continue to collect back-up data for the other parmeters, σ_θ was disconnected eliminating any form of back up. The azimuth card was intermittant and the results were negative readings.
- Relative humidity at A6 -- the hydrograph had several malfunctions including a bad pen, a broken hair, and the strip chart spindle had been installed incorrectly. The hydrograph was sent to the manufacturer for repair of these problems.

2.3.4 Sound Level Measurement Program

Sound level measurements were made weekly from January 1-June 14, 1984, at locations shown in Figure 2.3-2. The equipment used was a Bruel R. Kjaer type 2225 integrating sound level meter. During February and March, four measurements at Site A10 were missed when the site was not accessible due to snow.

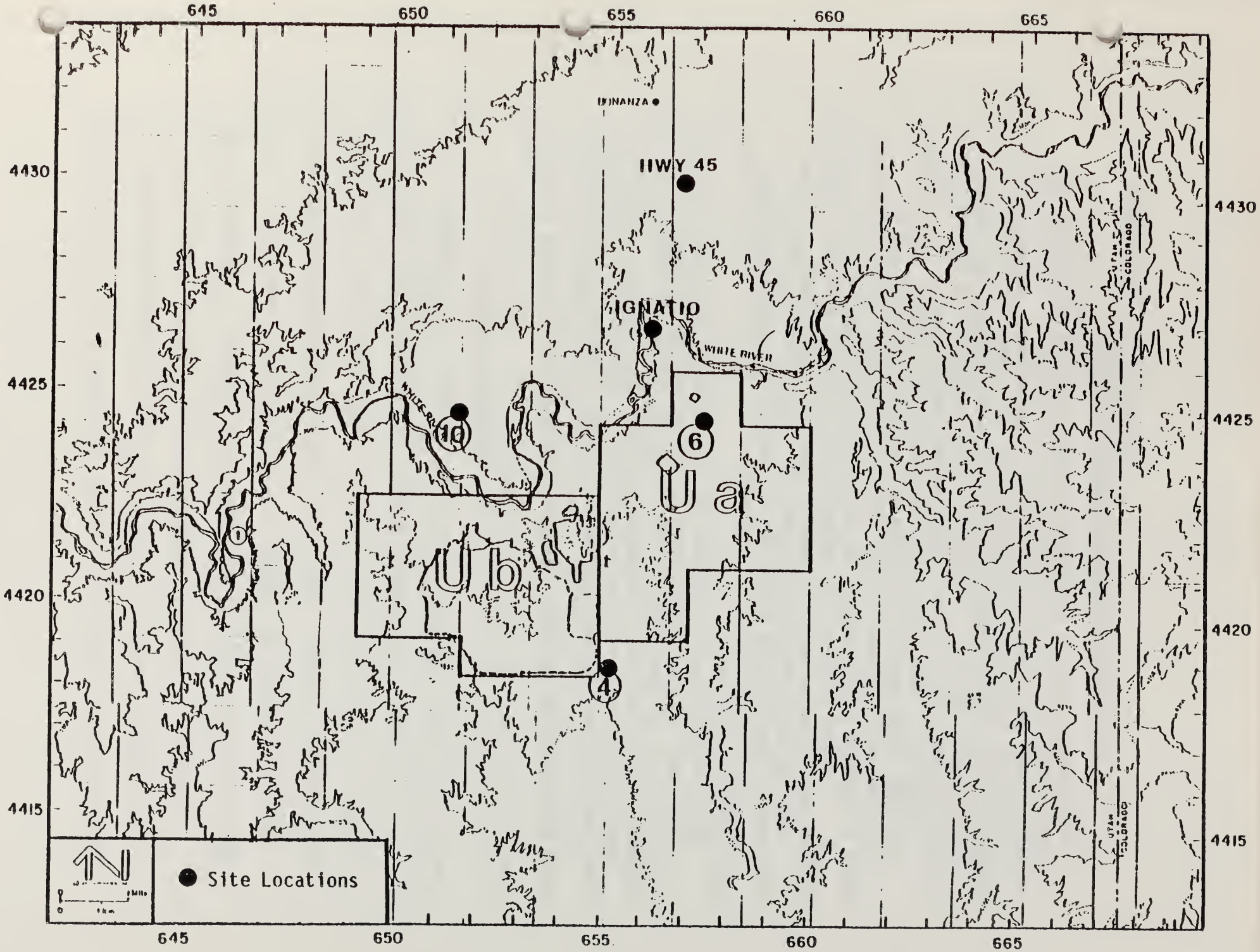


FIGURE 2.3-2. . Sound level measuring sites.

2.3.5 Quality Assurance/Quality Control Program

The internal quality assurance program including procedures for quality control and standard site operating procedures, are described in depth in the "Quality Assurance Plan for Air Resources Monitoring Oil Shale Lease Tracts Ua-Ub" (AV-QA-8047R2, AeroVironment Inc., 1982).

In 1984, four quarterly performance audits were performed the weeks of January 23-28, April 2-6, July 16-20, December 4-7. No major problems were discovered during any of the audits performed. All analyzers were in good working order and well within the operating limits based on EPA guidelines.

The annual external performance audit through the EPA Region VIII program was canceled due to budgetary constraints. However, the White River Shale project did participate in the EPA Hi-Vol Flow Rate Performance Survey in June of 1984. Results from this survey showed differences all less than 10% from the EPA values.

2.4 PROGRAM RESULTS AND ANALYSIS

2.4.1 Air Quality

In general, the background air quality on the tracts was typical for a remote rural area. The only pollutants present in any quantity were ozone and particulates, which often have a natural nonzero background level. Except for occasional spurts, all other instruments measuring pollutants were recording at their threshold limit most of the time, the same situation found during the baseline period.

The 1984 air quality data are compared with the baseline data (1975-1981) to determine if construction activities have caused any air quality impacts. Generally, the 1984 data are within the range of values observed during the years with no construction, so no significant impacts are apparent. The following sections describe the values observed for each parameter including a comparison to baseline conditions.

2.4.1.1 Gaseous Pollutants

A. Ozone (O_3) Trends of the seasonal average, minimum,and maximum ozone values from February 1975 through December 1984 are shown in Figure 2.4-1. The highest one-hour ozone value observed at the background site (A6/A4) was 163 $\mu g/m^3$ in May 1977. The peak values often occur in the summer, associated with a greater abundance of sunlight for O_3 formation. Generally, the peaks are slightly greater than 50% of the National Ambient Air Quality Standard (NAAQS) of 235 $\mu g/m^3$.

The highest monthly average of 98 $\mu g/m^3$ occurred in March 1984. The early part of this month was very cold and more stagnant than usual

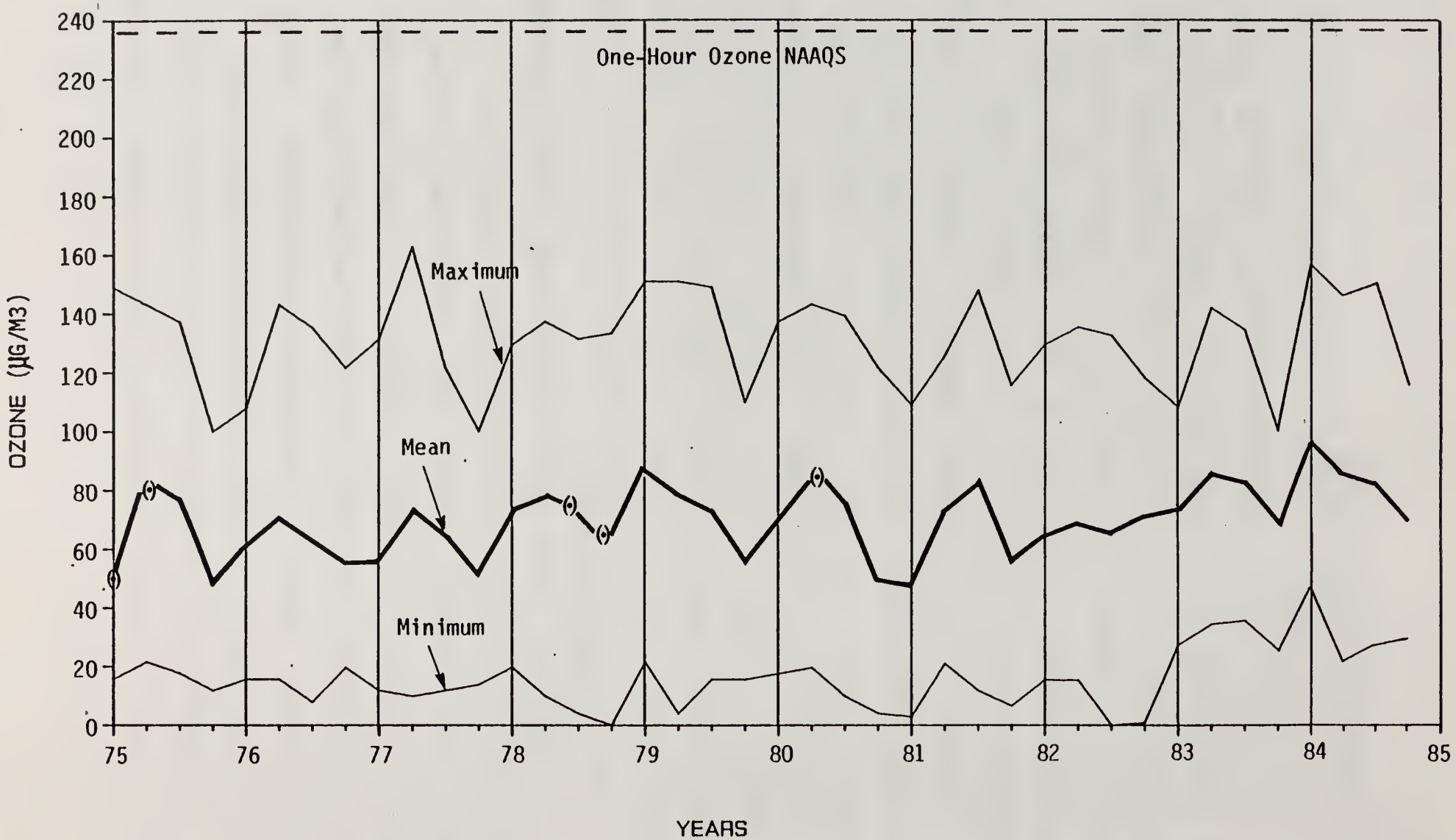


FIGURE 2.4-1. Seasonal minimum, mean, and maximum hourly ozone values from February 1975 through December 1984. (•) indicates data do not meet EPA (1977) averaging criteria.

due to a strong high pressure system over the region. These conditions were similar to February 1979, which had the second highest monthly average of 96 $\mu g/m^3$. According to Chan and Smith (1981), the ozone concentrations on the tracts depend a great deal on the ozone content of the troposphere. Year-to-year variability correlates with the passage of fronts over the site. Unusually high one-hour ozone concentrations (>100 $\mu g/m^3$) can be attributed to ozone intrusions accompanying frontal passages, strong atmospheric mixing that brings ozone from aloft to the surface, or long-range transport from urban areas.

Both the peaks and averages show a definite seasonal pattern from year to year, with a fairly constant trend of mean values. Table 2.4-1 shows that the seasonal and annual mean ozone concentration in 1984 was slightly higher than the baseline years, but that all 1984 values were within the range of baseline concentrations. The 1984 winter ozone level was above that found during baseline winters, but below the baseline spring maximum. Consistent with the baseline, the lowest 1984 seasonal mean and peak occurred in the fall. The highest and second highest one-hour ozone concentrations in 1984 were 154 and 151 $\mu g/m^3$, respectively, measured in March. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$ and the instrument's validity limit is ± 6 $\mu g/m^3$.

The diurnal distribution of hourly ozone concentrations is shown in Figure 2.4-2. Only the months of January and July are shown, but those months should be representative of the variation throughout the year. The daily minimum occurs in the early morning, while the maximum occurs in the afternoon. The difference between the morning and after-

TABLE 2.4-1. Comparison of seasonal minimum, mean and peak one-hour ozone concentrations ($\mu g/m^3$) between 1984 and baseline (1975-1981).

Season	Baseline (A6)			1984 (A4)		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Winter	3	66	151	47	94	154
Spring	4	74	163	22	84	145
Summer	4	74	149	27	80	147
Fall	4	52	133	29	67	114
Annual		66			82	

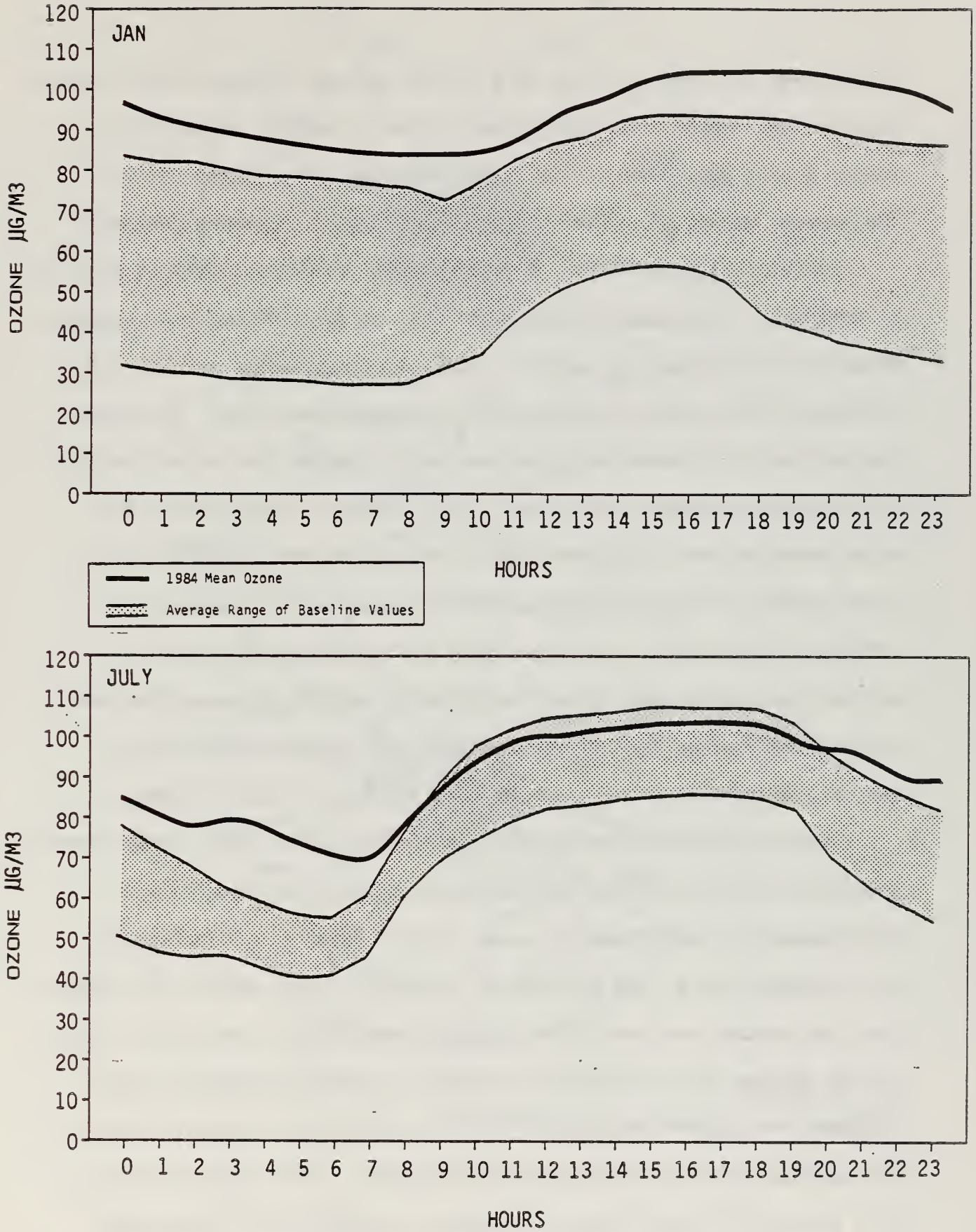


FIGURE 2.4-2. Diurnal distribution of hourly ozone concentrations for January and July 1984 compared to baseline.

noon values is larger in July than January due to increased solar insolation in that season. However, January shows a greater variation in values during each hour for the baseline range, most likely due to the greater amount of storms in winter and subsequent ozone intrusion.

The diurnal distribution of hourly ozone values for 1984 at Site A4 predominantly lies above the range of the average minimums and maximums measured during these two months in the baseline, except for the July afternoon values which are just within the observed range. In January, the regional high pressure system was much stronger than usual, contributing to more stagnant conditions. Also, regional ozone levels may have increased over past years due to increased ozone transport from other areas, although the exact contribution at this site would be difficult to pinpoint. It is unlikely that construction activities on the tract would contribute significantly to this increase from past observations, since the pollutants which form ozone (primarily NO_x and volatile organics) were not emitted locally in large amounts.

Figure 2.4-3 shows pollution roses for the 1984 annual ozone concentrations at Station A4 and for the baseline period at Station A6. The frequency of occurrence of ozone at both sites is predominantly split between the W, WNW and SE, SSE sectors. These sectors also represent the predominant wind directions for these sites. While this distribution implies that the ozone is related to general background conditions, it is significant that in 1984 over 40% of the concentrations >100 $\mu g/m^3$ were from the W, WNW and NW sectors. This observation is much higher than past years and supports the theory that the higher

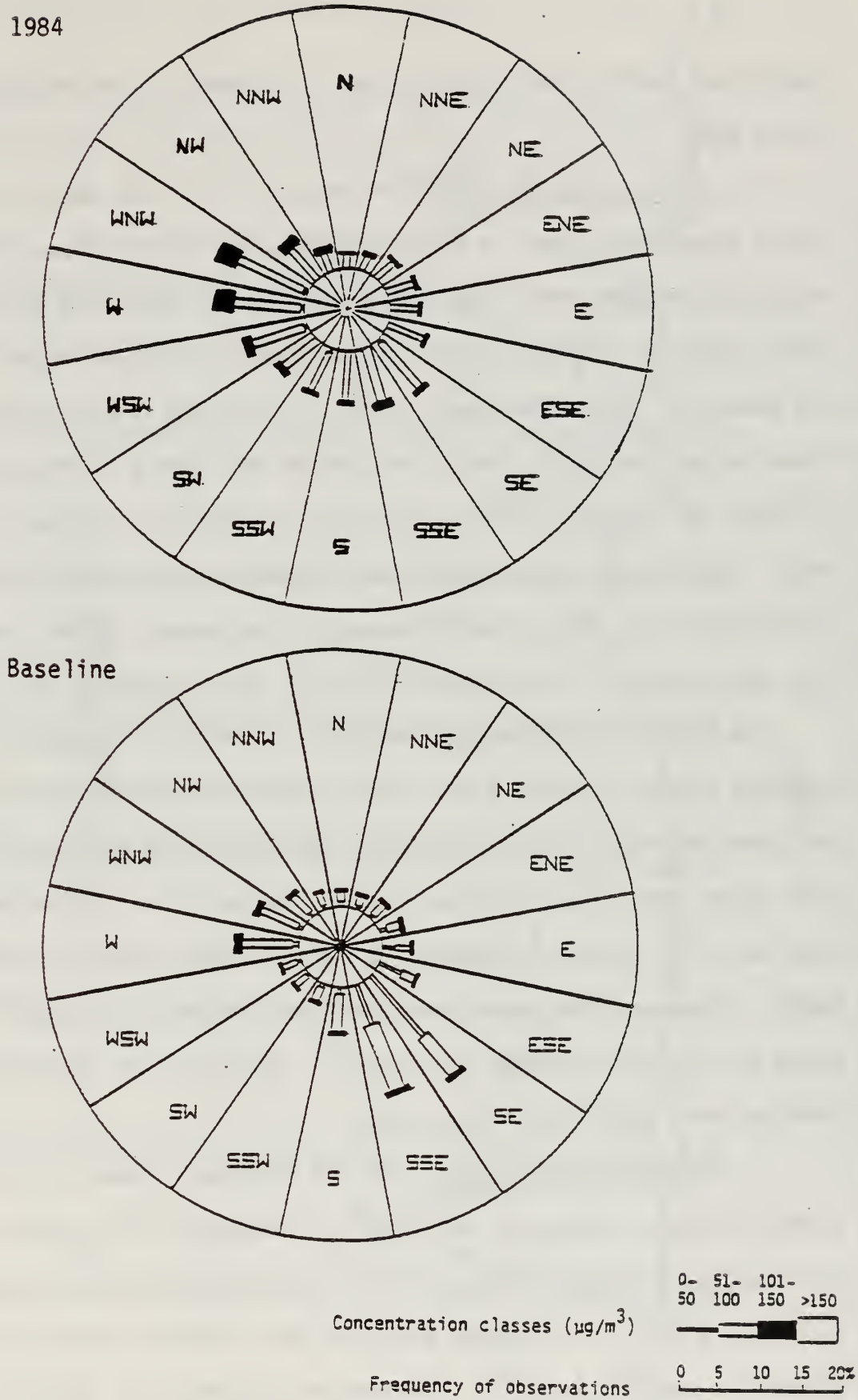


FIGURE 2.4-3. Ozone pollution roses for Site A4 for 1984 and Site A6 for the baseline period, 1975-1981.

than normal monthly averages are due to transport from populated areas in the West.

B. Carbon Monoxide (CO) The trend of CO values during the monitoring program is shown in Figure 2.4-4. This figure shows that all readings have been very low. The peaks are all less than 10% of the 1-hour NAAQS of 40 mg/m^3, with the maximum of 3.0 mg/m^3 occurring in the summer of 1975. The mean seasonal values are all less than 1.0 mg/m^3. These values are fairly consistent and do not show a strong seasonality at these low concentrations. Similarly, no definite diurnal patterns exist. The slight jump shown from mid-1980 to early-1984 is actually an artifact of changing the scale on the instrument, rather than a real data change. The detection limit of the instrument is 0.1 mg/m^3.

The seasonal CO means and maximums in 1984 are compared to similar baseline values in Table 2.4-2. All minimum concentrations are at the lower detection limit. Both the 1984 means and peaks are generally much lower than values observed during the baseline. The maximum one-hour value of 1.0 mg/m^3 observed in 1984 is much lower than the 40 mg/m^3 NAAQS. Likewise, the peak 1984 eight-hour value of 1.0 mg/m^3 is well below the applicable NAAQS of 10 mg/m^3. As during the baseline, the 1984 maximums occurred in the summer.

C. Nitrogen Dioxide (NO_2) Of the nitrogen oxides, only NO_2 has a NAAQS (annual average of 100 $\mu g/m^3$). The trend of NO_2 mean and maximum one-hour averages during the entire monitoring period is shown in Figure 2.4-5. Most values are very low, with means around the lower detection limit of 5 $\mu g/m^3$. The maximum concentration observed was

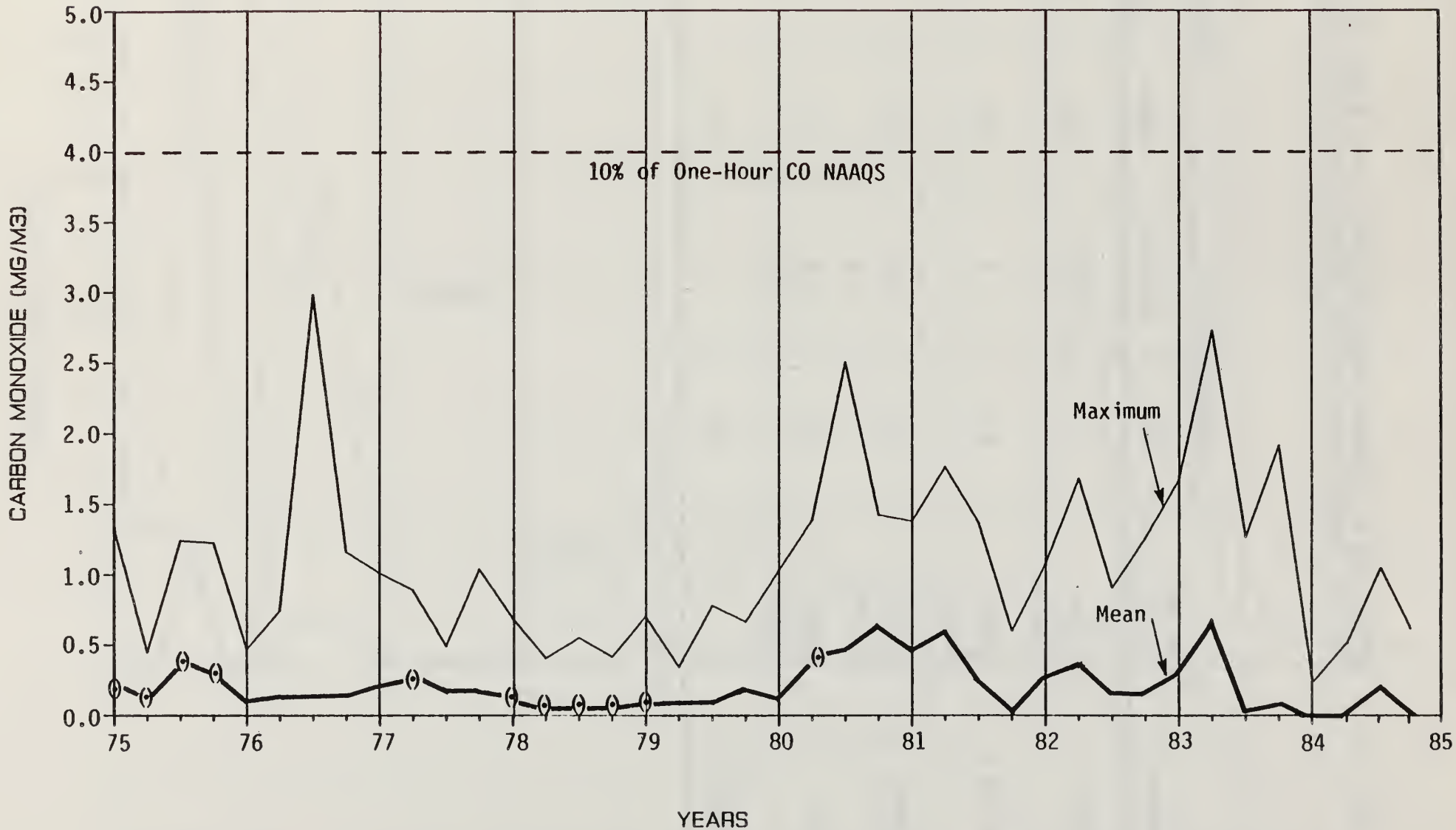


FIGURE 2.4-4. Seasonal trend of hourly maximum and mean carbon monoxide concentrations from February 1975 through December 1984. (•) indicates data do not meet EPA (1977) averaging criteria.

TABLE 2.4-2. Comparison of seasonal mean and peak 1- and 8-hour CO concentrations (mg/m^3) between 1984 and baseline (1975-1981).

Season	Averaging Time	Baseline (A6)		1984 (A4)	
		Mean	Maximum	Mean	Maximum
Winter	1-hour	0.2	1.4	0.0	0.2
	8-hours	-	1.2	-	0.1
Spring	1-hour	0.3	1.8	0.0	0.5
	8-hours	-	1.4	-	0.2
Summer	1-hour	0.2	3.0	0.2	1.0
	8-hours	-	1.8	-	1.0
Fall	1-hour	0.2	1.4	0.0	0.6
	8-hours	-	1.3	-	0.2
Annual		0.2		0.1	

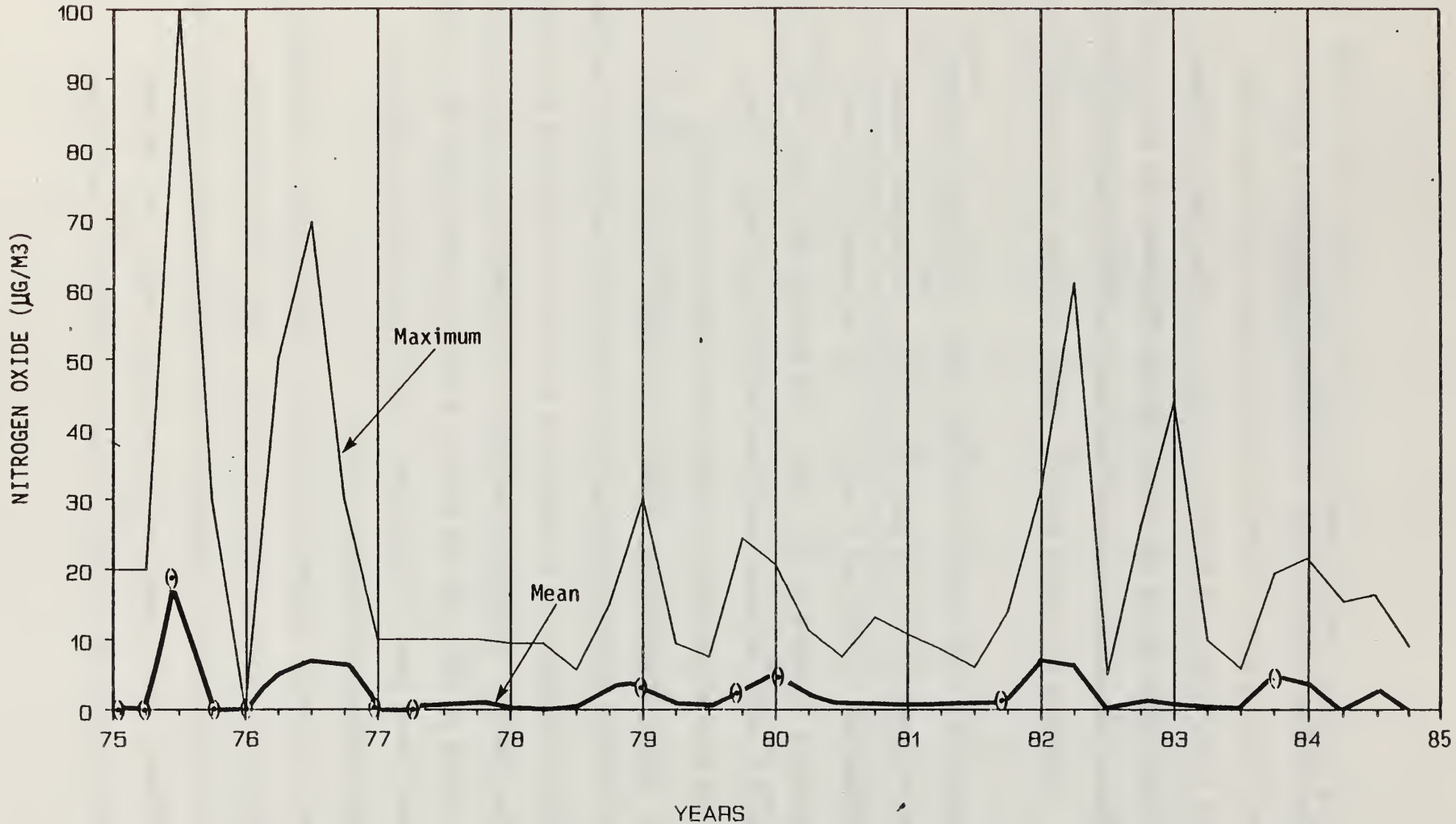


FIGURE 2.4-5. Seasonal trend of hourly NO_2 maximum and mean concentrations from January 1975 through December 1984. (•) indicates data do not meet EPA (1977) averaging criteria. (Note: NO_2 does not have a short-term NAAQS.)

100 μg/m^3 in the summer of 1975. The somewhat higher peaks shown in 1975 and 1976 and again in 1982 and 1983 are most likely associated with the higher levels of activity on tract in those years, although 1984 is low. Even during the higher periods, the means are consistently low, and all annual averages have been less than 5% of the 100 μg/m^3 NAAQS. No season or diurnal patterns appear at these low concentration levels.

Table 2.4-3 shows the 1984 seasonal means and maximums compared to those observed during the baseline period. The maximum one-hour average observed in 1984 was 21 μg/m^3. As a reference, California has a one-hour standard of 470 μg/m^3. The maximum 1984 annual NO_2 average of 1 μg/m^3 was much lower than the 100 μg/m^3 NAAQS. These values are within the range of values seen during the baseline.

D. Sulfur Dioxide (SO_2) Figure 2.4-6 shows the SO_2 trends of mean and maximum one-hour averages for all the years monitored. Maximum SO_2 levels throughout are extremely low at less than 4% of the 1,300 μg/m^3 three-hour NAAQS. The highest one-hour level observed was only 45 μg/m^3 in the spring of 1982, and the means are generally much below the 25 μg/m^3 instrument lower limit of detection. Similar to CO and NO_2, SO_2 does not show a seasonal or diurnal pattern.

For a numerical comparison, Table 2.4-4 shows the mean and maximum SO_2 levels during the baseline period and in 1984. The 1984 levels were within the baseline observations, although the seasonal distribution was different. With respect to the applicable NAAQS, the 1984 peak three-hour average was 22 μg/m^3 (versus a 1,300-μg/m^3 standard) and

TABLE 2.4-3. Comparison of seasonal mean and peak one-hour NO_2 concentrations ($\mu g/m^3$) between 1984 and baseline (1975-1981).

Season	Baseline (A6)		1984 (A4)	
	Mean	Maximum	Mean	Maximum
Winter	1*	30	3	20
Spring	2	47	<1	15
Summer	2	100	2	16
Fall	3*	36	<1	8
Annual	2		1	

* Less than five seasons.

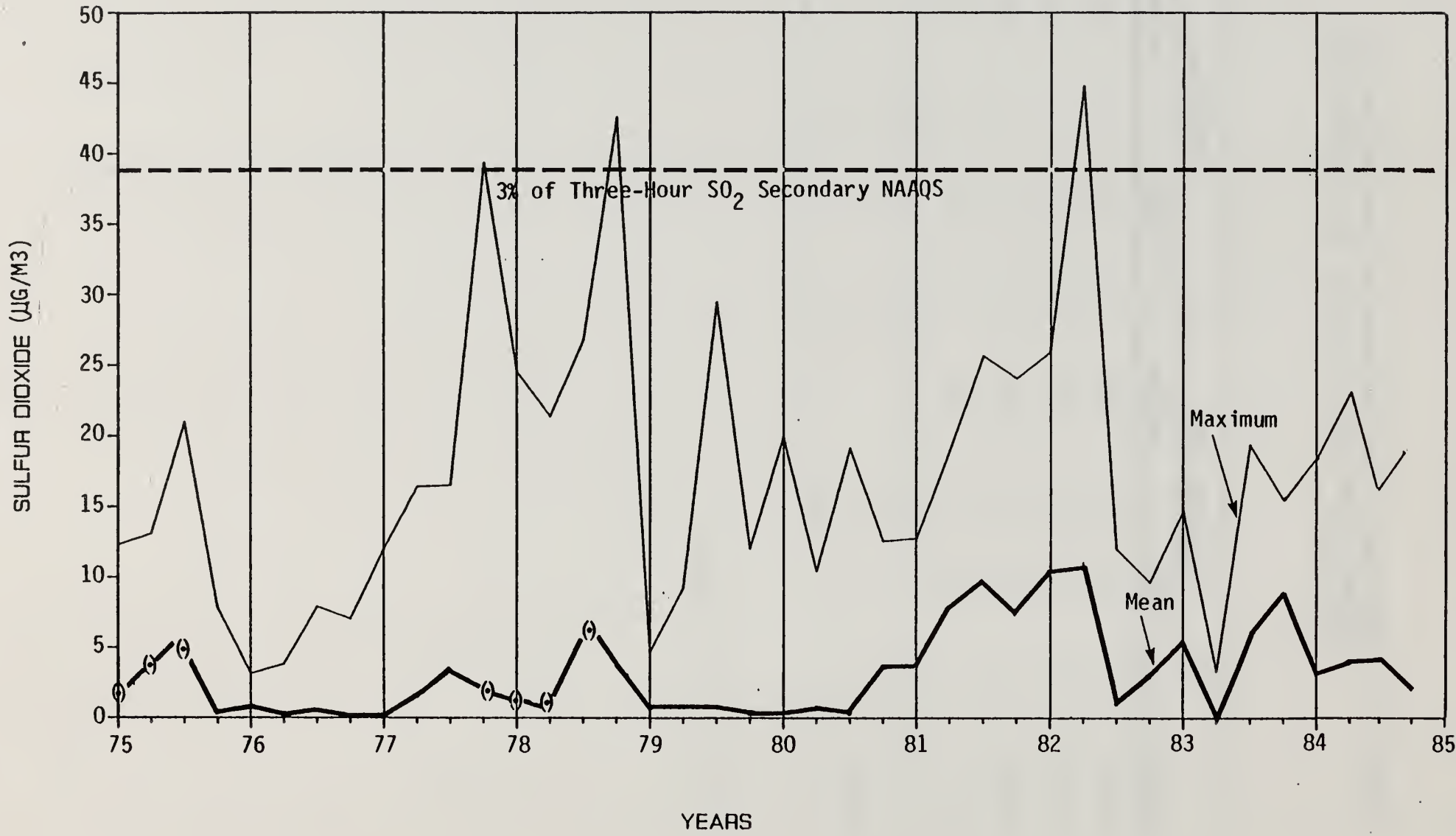


FIGURE 2.4-6. Seasonal trend of hourly SO_2 maximum and mean concentrations from January 1975 to December 1984. (•) indicates data do not meet EPA (1977) averaging criteria.

TABLE 2.4-4. Comparison of seasonal mean and peak three- and 24-hour SO_2 concentrations ($\mu g/m^3$) between 1984 and baseline (1975-1981).

Season	Averaging Time	Baseline (A6)		1984 (A4)	
		Mean	Maximum	Mean	Maximum
Winter	3-hour	1	18	3	9
	24-hour	-	11	-	6
Spring	3-hour	2	16	4	22
	24-hour	-	13	-	17
Summer	3-hour	3	24	4	16
	24-hour	-	16	-	10
Fall	3-hour	3	25	2	17
	24-hour	-	17	-	9
Annual		2		3	

the highest 24-hour average was 17 $\mu g/m^3$ (versus a 365-$\mu g/m^3$ standard). SO_2 also has an annual NAAQS of 80 $\mu g/m^3$, much above the 3 $\mu g/m^3$ average observed in 1984.

2.4.1.2 Particulates Only total suspended particulates (TSP) were monitored in 1984. Two samplers were operated at station A4, one the "designator" and the other the "collocator." The collocator was only operated every sixth day, timed to coincide with the three-day designator schedule used. The collocator was used to determine the precision of the TSP data; accuracy is determined through periodic audits. Standard procedures were used to determine precision and accuracy, as specified in the PSD guidelines Section 6.3.2.1 and 6.3.2.2 (U.S. EPA, 1978), and 44 Federal Register 27477 (May 1979).

Table 2.4-5 shows the computed precision and accuracy of the TSP samples during days when both the designator and collocator were operating simultaneously. The range of the 95% confidence limits is attributed to the low concentrations recorded. For example, a difference of 1 $\mu g/m^3$ at values less than 20 $\mu g/m^3$ is significant, whereas at higher values, the difference would not be as significant. The U.S. EPA PSD guidelines require accuracy to be within $\pm$15%; Table 2.4-5 shows that the accuracy for the designator and collocator samples for 1984 was well within this range (the maximum percent difference of -2.63% was found during the January audit).

The seasonal minimum, mean, and maximum TSP trends for all years at the background site are shown in Figure 2.4-7. Total suspended particulates have a natural elevated background, particularly in arid

TABLE 2.4-5. Precision and accuracy of the TSP samplers at Site A4 during 1984.

Site	Reporting Period	Precision				Accuracy	
		No. of Collocated Samples	No. of Collocated Samples ≤ 20 ug/m^3	Confidence Limit		Audit Date	Percent Difference (Di)*
				Lower 95%	Upper 95%		
A4	January-March	11	10	-2.244	9.615	1/25/84	-2.63
A4	April-June	17	12	-7.668	8.488	4/03/84	1.38
A4	July-September	14	10	-12.085	13.694	7/19/84	-.64
A4	October-December	12	12	-7.667	17.723	12/05/84	-.42

$$*Di = \frac{Yi - Xi}{Xi} \; 100$$

-- known flow rate (m^3/min) = Yi

-- audit flow rate (m^3/min) = Xi

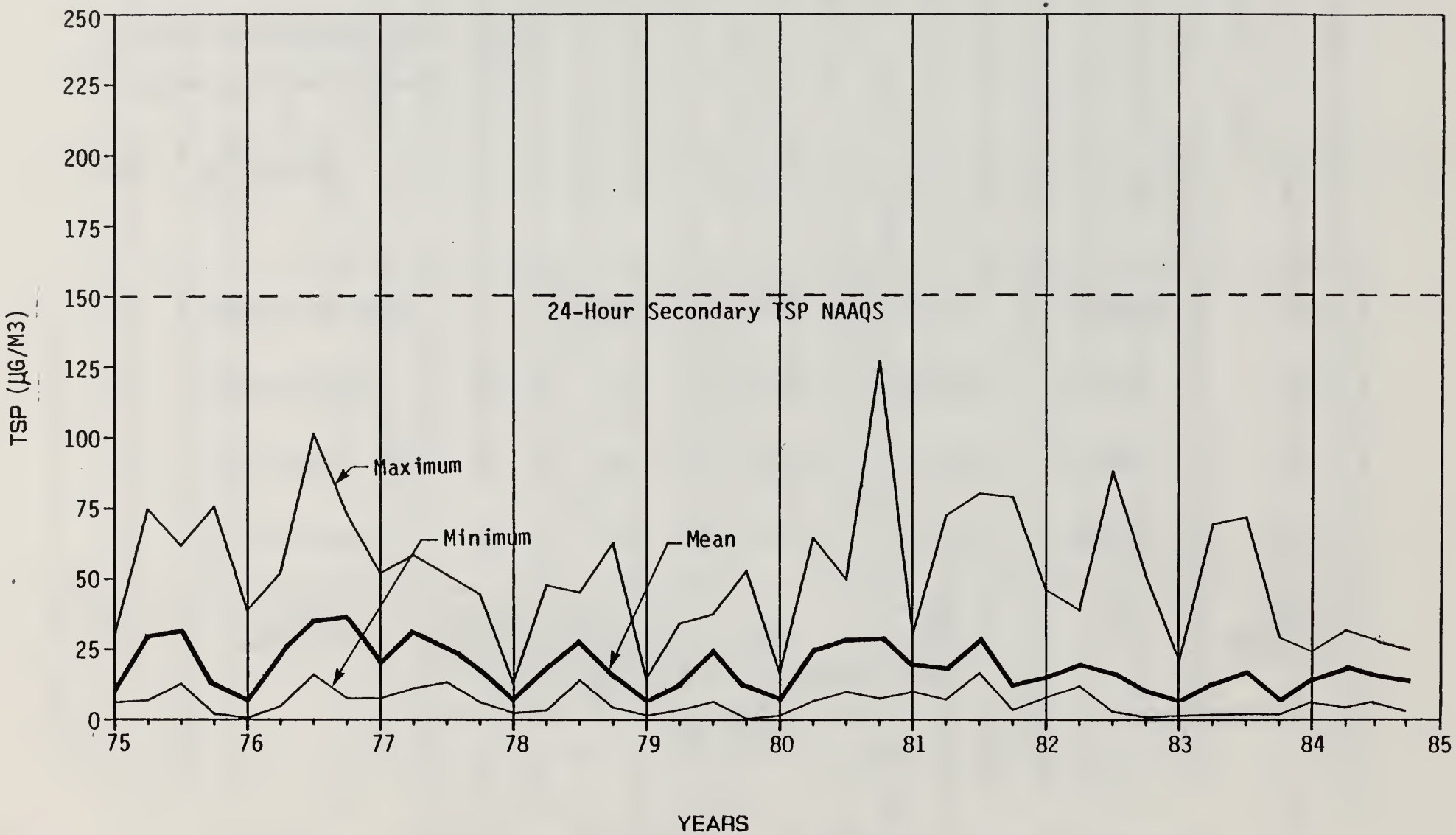


FIGURE 2.4-7. Seasonal minimum, geometric mean and maximum 24-hour TSP trends from January 1975 through December 1984 at the background site.

climatic conditions where due to low soil surface moisture and sparse ground cover, the wind can cause soil erosion. The general dustiness of the tracts is reflected in the graph, which shows means around 40% of the annual secondary NAAQS (60 $\mu g/m^3$), and maximums up to 85% of the 24-hour secondary NAAQS (150 $\mu g/m^3$).

A definite seasonal pattern can be seen in this figure. The means show that generally high TSP values occur in late-spring and summer when winds are highest and precipitation the least. However, the yearly maximums show more irregularity, with dust events occurring from spring through fall, depending on the wind, moisture and tract activity. For example, the peak value of 127 $\mu g/m^3$ occurred in the fall of 1980. The lowest maximums have always occurred in the winter. The overall maximums in 1984 were the lowest in the 10-year program.

Table 2.4-6 compares the 1984 geometric mean, minimum, and maximum values from A4 and A10 to the baseline values at A6. Both the background station (A4) and impact station (A10) show comparable values with each other and are considerably lower than the baseline. The maximum 24-hour values at the two sites in 1984 were 29.1 $\mu g/m^3$ (A4) and 34.8 $\mu g/m^3$ (A10), both under one fourth of the standard. The maximum at A4 occurred in May and in September at A10. (There was no reading at A4 on the day in September that was the highest at A10.)

Only two of the sampling days in 1984 (99 total) had concentrations over 30 $\mu g/m^3$. The uniformity of TSP levels at both stations A4 and A10, combined with very low below-baseline-level concentrations, implies that there are no appreciable impacts at the monitoring locations

TABLE 2.4-6. Comparison of seasonal geometric means, standard geometric deviations, maximum and minimum 24-hour particulate concentrations ($\mu g/m^3$) between 1984 and baseline (1975-1981).

	Season	Baseline (A6)	1984 (A4)	1984 (A10)
Geometric Mean	Winter	9.9	11.1	10.4
	Spring	21.8	13.6	13.2
	Summer	28.2	13.9	13.5
	Fall	17.7	8.1	9.0
	Annual	18.2	11.5	11.7
Standard Geometric Deviations	Winter	2.2	1.5	1.5
	Spring	2.0	1.8	1.8
	Summer	1.6	1.5	1.7
	Fall	2.6	2.5	1.9
	Annual	2.3	1.8	1.8
Maximum 24-hour Average	Winter	51.9	24.1	17.3
	Spring	74.7	29.1	24.6
	Summer	101.2	26.8	34.8
	Fall	127.0	23.4	23.8
Minimum 24-hour Average	Winter	0.7	5.0	3.7
	Spring	3.3	2.5	3.0
	Summer	6.5	4.4	3.7
	Fall	0.5	2.3	2.1

attributable to the construction activities (which are mostly dust generating) in 1984.

The annual and seasonal geometric means at both sites were also very similar and somewhat lower than baseline. The geometric mean given can be considered to correspond to the concentration expected 50% of the time because particulate concentrations are generally log-normally distributed. The geometric mean particulate concentration during 1984 ranged from 8.1 $\mu g/m^3$ during the fall months to 13.9 $\mu g/m^3$ during the summer. The annual geometric mean values of 11.5 $\mu g/m^3$ (A4) and 11.7 $\mu g/m^3$ (A10) are well below the 60 $\mu g/m^3$ annual secondary TSP NAAQS.

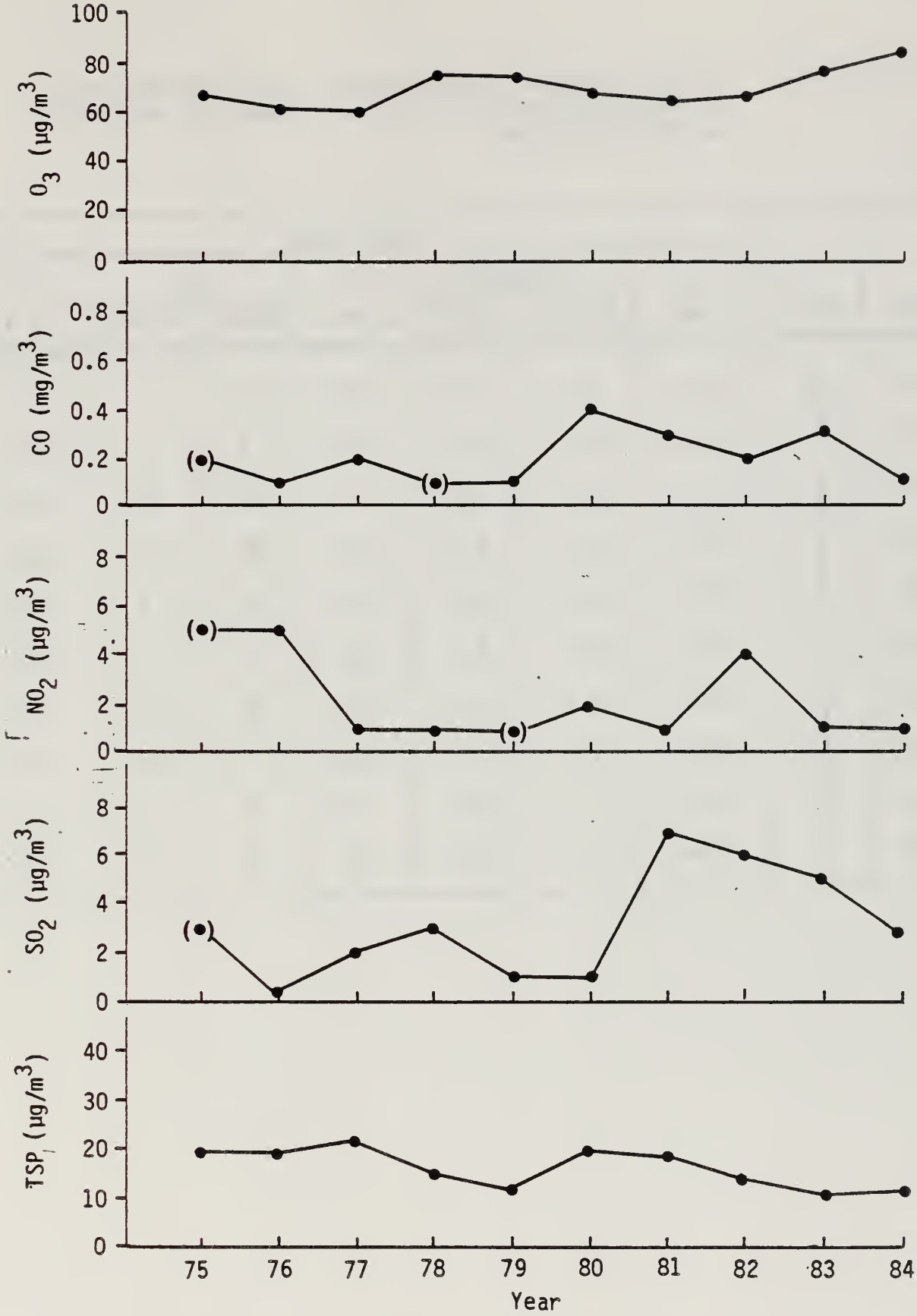
2.4.1.3 Air Quality Data Summary To summarize the air quality data discussed in the preceding sections, Table 2.4-7 shows the annual averages (geometric means for TSP) for all the pollutants for all the monitored years. As discussed, O_3 and TSP show a consistent nonzero background, and the others, CO, NO_2 and SO_2, are all around the lower limit of detection for those instruments. These annual averages are plotted in Figure 2.4-8 to see if there was any simultaneous trend among the various pollutants; no consistencies are apparent. 1984 was high for ozone but comparatively low for all other pollutants.

All of the maximum short-term averages corresponding to NAAQS are tabulated in Table 2.4-8. Again, no real pattern appears from year to year except that the values of any one pollutant are fairly constant. The data criteria used to compute these averages is given in Table 2.4-9.

TABLE 2.4-7. Annual average (gaseous) and annual geometric mean (particulates) pollutant concentrations for the entire monitoring period.

Year	Site	Pollutant				
		O_3 µg/m^3	CO mg/m^3	NO_2 µg/m^3	SO_2 µg/m^3	TSP µg/m^3
75	A6	67	(0.2)	(5)	(3)	19.5
76	↓	62	0.1	5	<1	20.4
77		61	0.2	1	2	22.6
78		74	(0.1)	1	3	15.0
79		73	0.1	(1)	1	12.5
80		68	0.4	2	1	19.6
81		65	0.3	1	7	18.5
82	↓	67	0.2	4	6	14.4
83	A4 ↓	77	0.3	1	5	10.7
84	↓	82	0.1	1	3	11.5

( )Averages based on data of insufficient quantity to meet EPA (1977) criteria.



(•) Averages based on data of insufficient quantity to meet EPA (1977) criteria.

FIGURE 2.4-8. Trends of annual averages of all pollutants during the monitoring program at the background station.

TABLE 2.4-8. Maximum observed concentrations ($\mu g/m^3$) corresponding to relevant short-term averaging times for the entire monitoring period.

Year	Site	Pollutants						
		O_3 (1-hr)	CO (mg/m^3) (1-hr)	CO (mg/m^3) (8-hr)	NO_2 (1-hr)	SO_2 (3-hr)	SO_2 (24-hr)	TSP (24-hr)
75	A6	149	1.3	1.0	100	21	13	75.6
76	↓	143	3.0	1.8	70	6	4	101.2
77	↓	163	1.0	0.9	13	16	10	58.3
78	↓	137	0.7	0.4	15	25	15	62.7
79	↓	151	0.8	0.7	30	19	4	52.9
80	↓	143	2.5	1.5	21	17	9	127.0
81	↓	148	1.8	1.3	14	24	19	80.4
82	↓	135	1.7	1.2	61	37	23	75.9
83	A4 ↓	142	2.7	2.5	44	18	17	71.9
84	↓	154	1.0	1.0	20	22	17	29.1

TABLE 2.4-9. Averaging criteria, U.S. EPA, 1977.

Time Interval	Minimum Number of Observations
3-hour running average	3 consecutive hourly observations
8-hour running average	6 hourly observations
24-hour	18 hourly observations
Monthly	21 daily averages
Quarterly	3 consecutive monthly averages
Yearly	9 monthly averages with at least two monthly averages per quarter

None of the values in these tables exceed any of the NAAQS. For easy reference, the maximum concentrations observed in 1984 are compared to these standards in Table 2.4-10. Ozone approaches 70% and TSP 25% of their respective standards, with all others very low.

2.4.2 Atmospheric Processes

In order to predict what future air quality impacts are likely from a large-scale oil shale development, a thorough understanding of the atmospheric conditions into which emissions will be released is vital. Previous measurements have included both special experiments and routine long-term monitoring. These routine measurements were continued in 1984 and will be discussed and compared to the baseline in the following sections.

2.4.2.1 Climate Before discussing the details of the transport and dispersion characteristics of the atmosphere over the Ua-Ub tracts, it is appropriate to summarize the major weather systems that affect the large-scale movement of air masses over the area.

The horizontal transport of an air mass is a consequence of large-scale differences in air pressure. The factor determining Utah's weather during the winter months is the location and strength of the Intermountain Region High Pressure Cell. Figure 2.4-9a shows the normal January sea-level pressure and temperature. Storm tracks during mid-winter tend to pass north through Montana and through southern Utah. After February, storm tracks are more prevalent over northern Utah as the strength of the Basin High wanes. Precipitation is highest during the spring months.

TABLE 2.4-10. Comparison between national and Utah air quality standards for air pollutants with maximum levels observed for the Ua/Ub tracts in 1984.

Pollutant	Averaging Time	Primary Standards	Secondary Standards	Maximum 1984 Concentrations
Ozone (O_3)	1-hour	235 $\mu g/m^3$ (0.12 ppm)	Same as primary	154 $\mu g/m^3$
Carbon monoxide (CO)	8-hour	10 mg/m^3 (9 ppm)	Same as primary	1.0 mg/m^3
	1-hour	40 mg/m^3 (35 ppm)	Same as primary	1.0 mg/m^3
Sulfur dioxide (SO_2)	annual average	80 $\mu g/m^3$ (0.03 ppm)	-	3 $\mu g/m^3$
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	-	17 $\mu g/m^3$
	3-hour	-	1,300 $\mu g/m^3$ (0.5 ppm)	22 $\mu g/m^3$
Nitrogen dioxide (NO_2)	annual average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary	1 $\mu g/m^3$
Total suspended particulates (TSP)	annual geometric mean	75 $\mu g/m^3$	60 $\mu g/m^3$	11.7 $\mu g/m^3$
	24-hour	260 $\mu g/m^3$	150 $\mu g/m^3$	34.8 $\mu g/m^3$

FIGURE 2.4-9. Normal sea level pressure in mb (solid lines) and temperature in ^{o}F (dashed lines).

Source: National Weather Bureau, 1952.

During the summer months (Figure 2.4-9b), the pressure is lower, and sporadic moisture from the Gulf of Mexico brings periods of scattered thundershowers. Beginning in September, the storm fronts from the north increase in probability but are interspersed with many periods of clear weather when high pressure builds up in the Intermountain Basin.

Many deviations from the normal climatological trends in Utah were experienced in 1984.

In January and February, the Intermountain Region High Pressure Cell was much stronger than usual resulting in extremely cold temperatures and stagnant conditions. The mean storm track was displaced into Canada causing precipitation totals to be below normal. March reverted to springtime trends with near normal precipitation and temperatures.

April was very stormy and cold as numerous storms contributed to a record snowpack in the mountain of Northeastern Utah. May and June were both warmer than normal inducing heavy snowmelt and flooding in the valleys. Precipitation amounts were below normal in May and above normal in June.

In July, August and September the intermountain region experienced frequent intrusions of subtropical moisture. Locally heavy showers and thunderstorms occurred in the mountains and deserts. Precipitation amounts were well above normal. Temperatures were near normal.

A series of winter-like storms struck the intermountain region in October producing heavy snows and temperatures much below normal.

On the 18th, Utah experienced the most severe early season snowstorm on record. Salt Lake City established an all time record snowfall of 18.4 inches in a 24-hour period. November and December were warmer than normal. Precipitation was below normal in November and above normal in December, with both months having occasional heavy snowfalls.

2.4.2.2 Meteorology 1984 meteorological data are summarized below and compared to baseline data (1975-1981) to identify significant deviations.

A. Surface Wind Flow Table 2.4-11 lists monthly average and peak wind speed and prevailing direction for the five monitoring stations during 1984. These data are similar to wind observations made in previous years, except for January and February which are lower than normal. This occurrence was explained in the preceding secion as probably due to the position of the Intermountain Region High Pressure System. Figure 2.4-10 shows the seasonal mean and peak wind speed (10 m) for the monitoring period at A6. The mean wind shows a definite seasonal pattern, with generally the highest winds in spring and summer and lowest in fall and winter. The peaks show more irregularities, with some peaks in fall and winter likely associated with storms. However, spring peaks are the most prevalent.

Three general surface wind flow patterns have been identified from this program: a nighttime drainage flow, a transitional upslope flow and midday westerly flow. The drainage and upslope flow are influenced by topography, whereas the midday flow is induced by synoptic conditions.

TABLE 2.4-11. Monthly average and peak wind speeds (mph) and prevailing directions for 1984.

1984 Month	Site A4			Site A6			Site A10			Site A11			Site A13		
	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.
JAN	1.4	9.9	W	2.8	9.0	SSE	2.2	8.3	WNW	3.3	8.7	WNW	1.8	7.0	NW
FEB	1.9	14.6	W	3.0	11.8	SE	1.1	8.4	NNE	3.9	16.8	WNW	2.0	10.4	NW
MAR	3.1	22.0	W	4.4	22.3	SE	1.9	18.3	N	4.9	17.0	ESE	3.2	15.2	NW
APR	6.1	25.3	W	6.8	28.2	SSE	4.0	21.2	NNE	7.2	29.0	SE	5.7	21.7	SSE
MAY	6.7	24.1	WNW	8.1	28.8	SSE	4.7*	16.6*	WNW	8.6	28.7	NW	6.4	21.5	NW
JUN	5.1	20.7	SE	7.6	26.8	SSE	3.9	19.6	NNE	7.9	24.0	SE	5.7	18.4	S
JUL	5.1	19.5	WNW	6.1	21.1	SSE	3.2	16.2	NNE	6.8	21.9	SSE	5.1	17.0	SSE
AUG	4.6	17.1	WNW	5.9	21.3	SSE	2.9	19.9	NE	6.5	18.2	SSE	4.7	17.6	SSE
SEP	5.6	25.7	WNW	7.0	26.4	SSE	4.0	22.8	NE	7.3	28.6	SE	5.5	22.4	WNW
OCT	5.0	19.8	W	6.1	23.4	S	3.4	18.8	NE	6.5	19.8	SSE	4.8	18.0	SSE
NOV	4.3	22.2	W	5.4	24.7	SSE	2.6	22.5	NNE	5.9	27.0	SE	3.8	19.0	WNW
DEC	3.0	19.7	W	3.3	22.3	SSE	1.5	21.4	N	4.3	19.5	NW	2.4	15.5	SE
Annual	4.3	25.7	W	5.5	28.8	SSE	3.0	22.8	NNE	6.1	29.0	SE	4.3	22.4	NW

*Low data recovery (less than 60%).

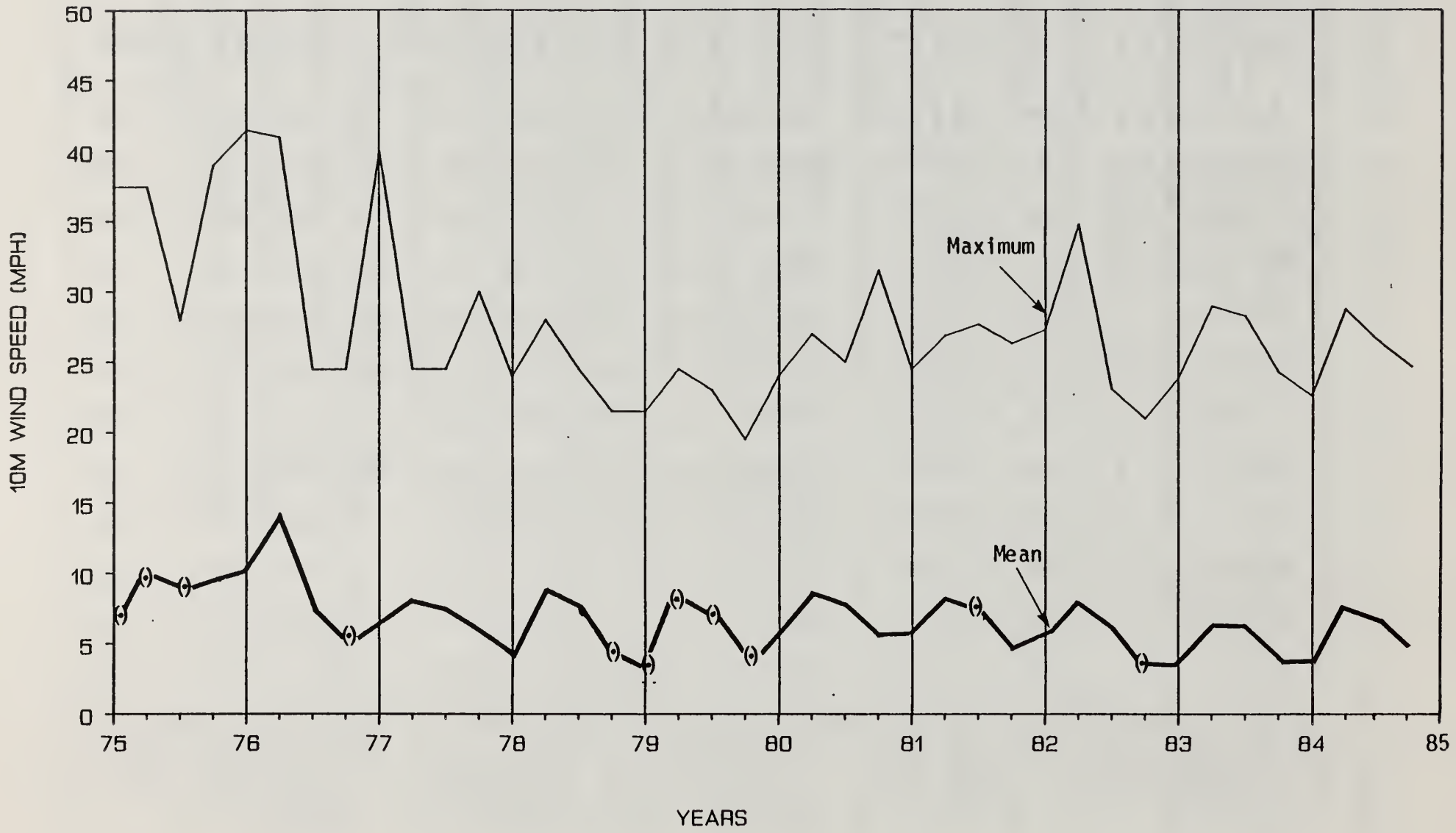


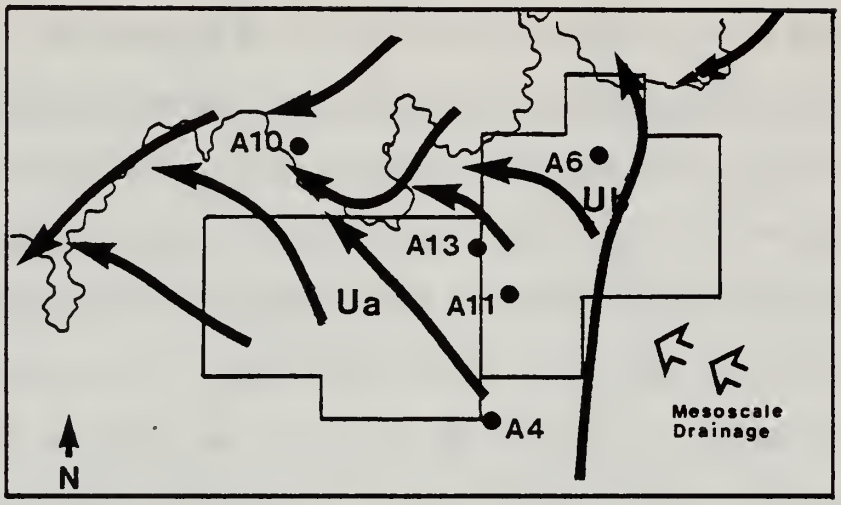
FIGURE 2.4-10. Seasonal mean and peak hourly wind speed (10 m) trends for the monitoring period at A6. (•) indicates data do not meet EPA (1977) averaging criteria.

Figure 2.4-11a plots streamlines for drainage flow. The arrows on the figure are general flow streamlines representing early morning hour conditions with mesoscale drainage flow. The drainage flow occurs most often of the three flows, usually from late afternoon through early morning during periods of fair weather. Air flows from higher to lower terrain, down gullies and creek beds. The drainage flow is from the SE at A4, SSE at A6, NE at A10, SE at A11, and SSE at A13. The dominance of this flow is usually reflected in the annual prevailing wind directions. 1984 was an unusual year for Site A4, as westerly synoptic winds were the prevailing ones.

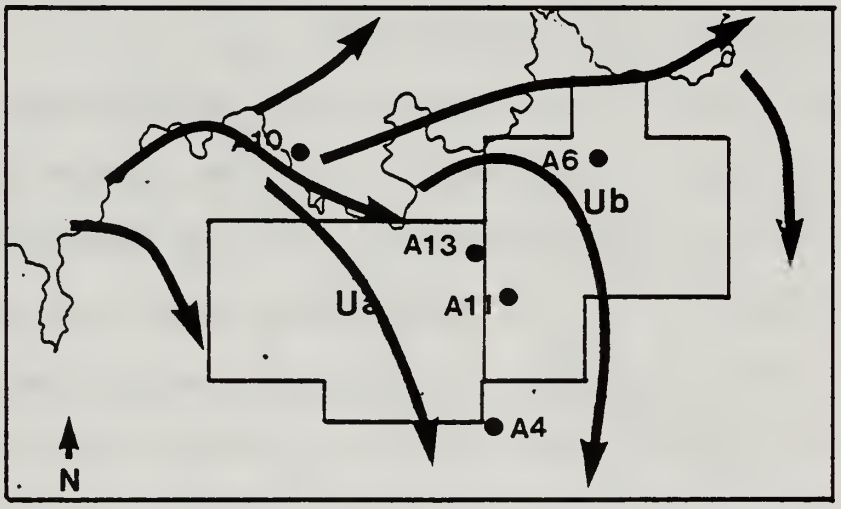
Figure 2.4-11b plots an upslope wind flow that occurs between drainage and synoptic flow periods. Since this pattern is transitional, it generally lasts less than an hour. It is an important factor in pollutant dispersion since plume fumigation would occur under this condition. The surface-based inversion that results from strong radiative cooling begins to lose some of its strength shortly after sunrise. As the morning progresses, the heat gained on the surface from solar radiation exceeds that lost by terrestrial radiation and the soil temperature rises, warming the air above. This creates a pressure difference resulting in upslope flow. Because of its brevity, this pattern is lost in the hourly-average wind direction data. This pattern begins earlier during the summer months than during the winter when the sun rises later.

During midday and periods of instability or unsettled weather, synoptic-induced flows dominate. Figure 2.4-11c plots streamlines

a. Drainage flow during early morning hours



b. Transitional Flow



c. Afternoon synoptic flow

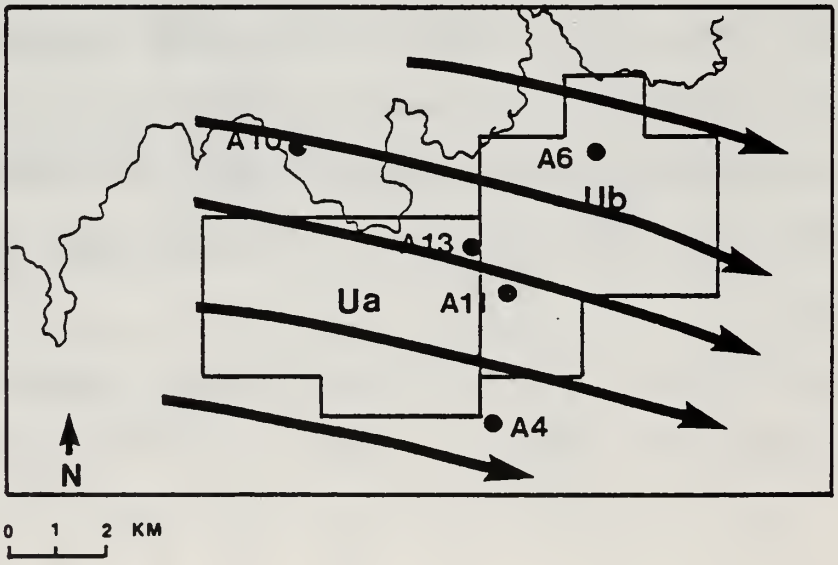


FIGURE 2.4-11. Typical flow pattern on Tracts Ua and Ub during 1975-1984.

for the afternoon synoptically-induced flow, which produce W to WNW winds over the entire tract. These afternoon flows are generally stronger during the warm months. The most exposed sites, such as A4 and A11, tend to be more influenced by synoptically-induced flow than less exposed sites, such as A10. This explains why A4 and A11 will record a prevailing westerly direction while other sites still record prevailing wind direction resulting from drainage flows during the same period. Because these sites are well exposed, A4 and A11 also usually record the highest average wind speeds. During especially stormy periods most stations on the tract recorded prevailing W to WNW wind directions because of the dominance of synoptic flow.

Figure 2.4-12 is a plot of A6 monthly averaged hourly wind speed data for January and July 1984. The span of lowest to highest monthly averaged diurnal hourly values during baseline is plotted on the same graph for these months. Similar to 1983, January 1984 means were slightly below the average baseline minimum, as were the July means for most of the diurnal cycle. As previously mentioned, January wind speeds were below normal. July also was below normal, probably because July was wetter than normal, with frequent tropical air masses passing further north than usual. The July distribution did closely follow the baseline pattern, however, with the lowest speeds occurring around dawn and the peaks in the afternoon. The differences between the January and July plots show the greater influence of slow drainage winds in the winter, when the morning versus afternoon wind speeds show less variation, but the presence of winter storms shows more variation in each of the individual hours.

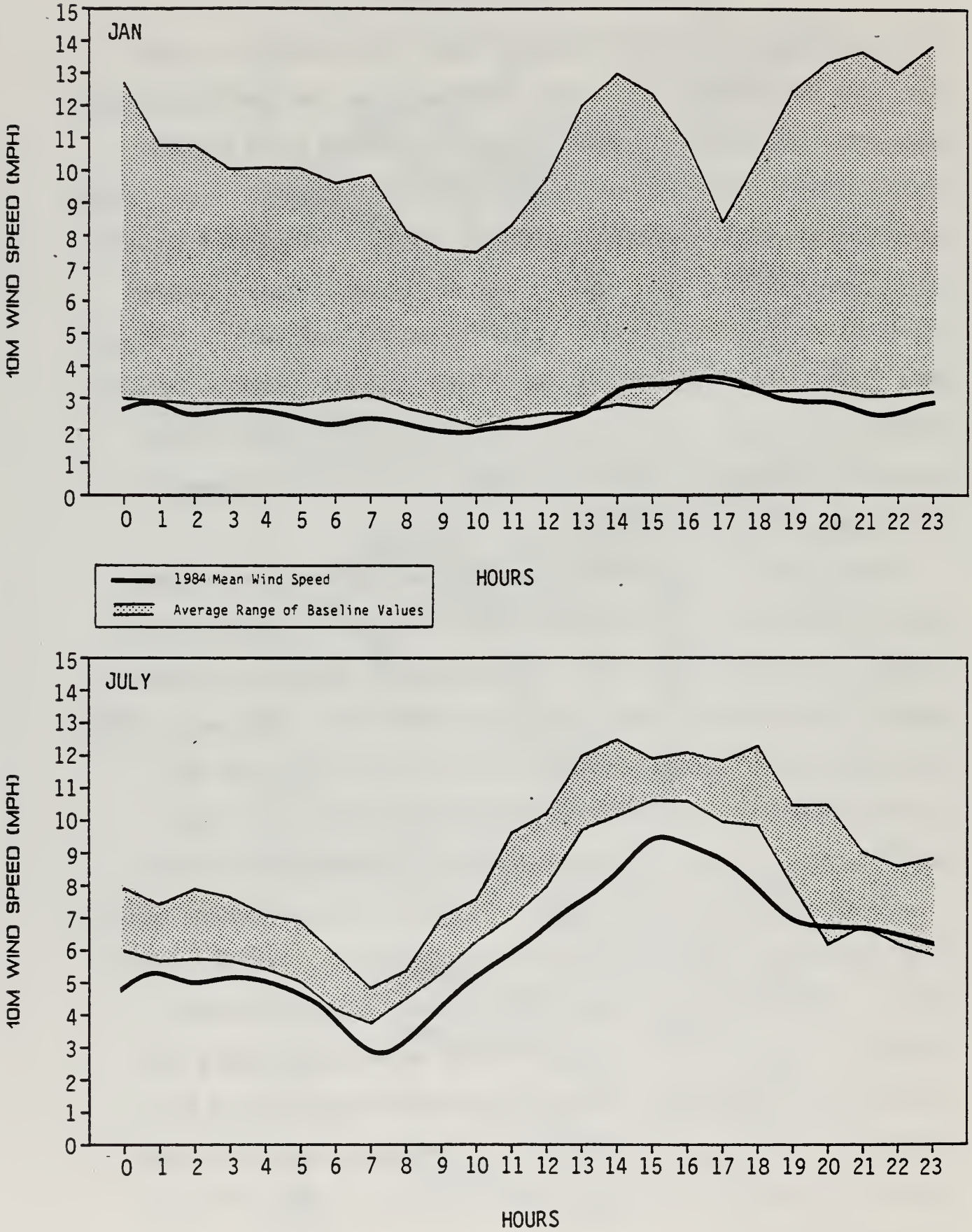


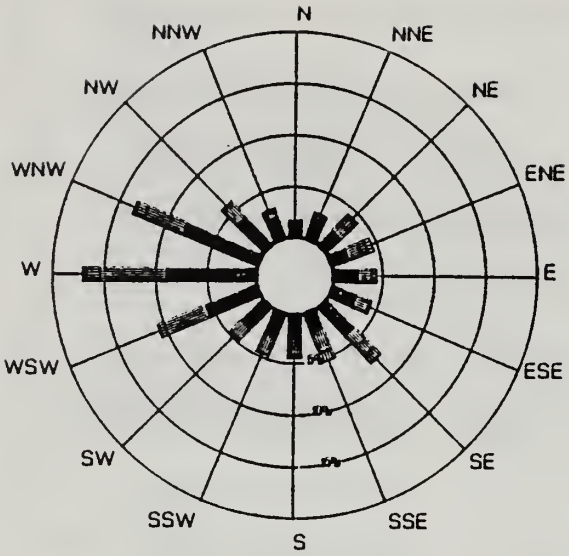
FIGURE 2.4-12. Monthly averaged hourly wind speed (10 m) for January and July 1984 versus baseline for Site A6.

Figures 2.4-13 through 2.4-17 are seasonal wind rose plots for the five wind monitoring stations. The length of each bar represents the frequency of winds from the directions toward which the bar points. These plots illustrate the dominance of drainage and synoptic flows at each of the sites. Only very minor differences exist from season to season with the lowest wind speeds occurring in winter.

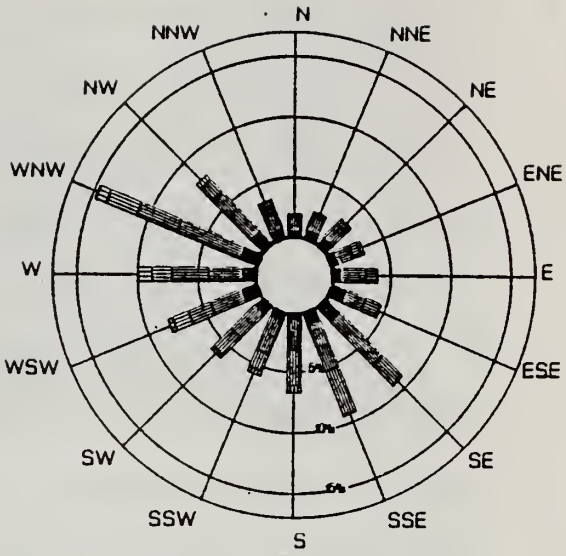
B. Temperature Figure 2.4-18 plots seasonal mean, maximum and minimum temperatures for 1975 through 1984 at A6. There are no significant differences between 1984 and baseline data. During the program, the highest temperature observed at A6 was 36°C in August 1983 and the lowest was -30°C in January 1979. 1984 nearly matched both of these records with a 34.4°C reading in July and a -29.9°C in January.

Table 2.4-12 lists monthly mean, maximum and minimum temperature for the five meteorological monitoring stations. During 1984, the highest temperature observed was 38.9°C at A13 during August, and the lowest temperature was -29.9°C at A6 during January. Annual mean temperatures ranged from 5.4°C at A11 to 7.3°C at A4. This table shows that January and February were very cold months this year, with only one day in the two months having a few hours above 0°C at A4, A6 and A10.

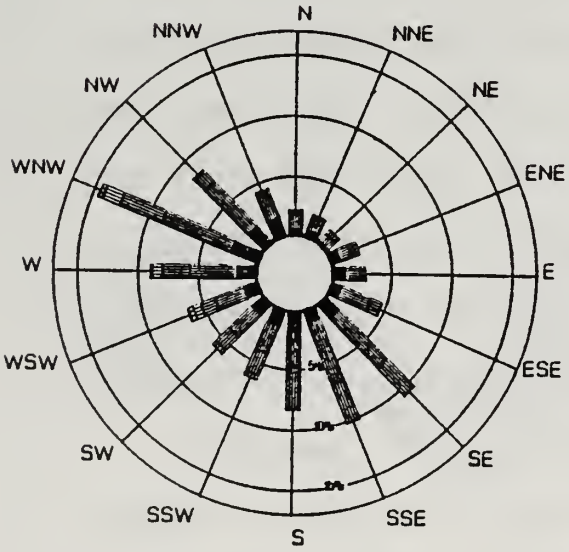
Figure 2.4-19 compares January and July 1984 mean hourly temperatures to the baseline temperature range for Site A6. Temperatures in January and July occurred at the lower edge of the baseline ranges, closely following the normal diurnal pattern. In general, the maximum temperatures are observed between 1400 and 1600 MST, and the minimum temperatures, between 0400 and 0800 MST.



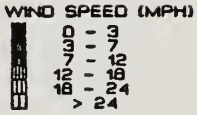
January-March

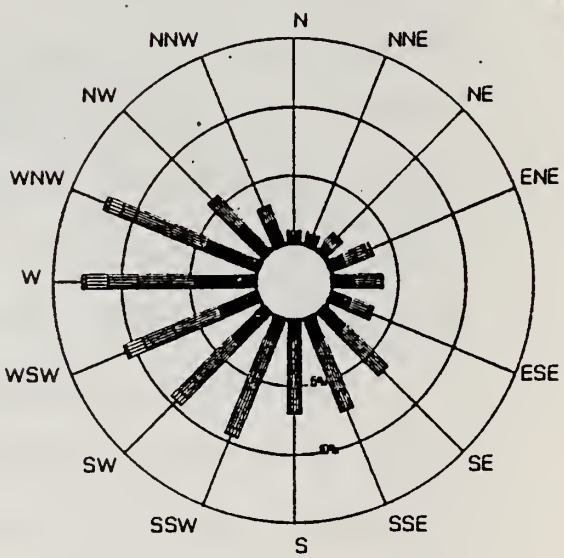


April-June



July-September





October-December

FIGURE 2.4-13. Seasonal wind roses for Site A4 in 1984.

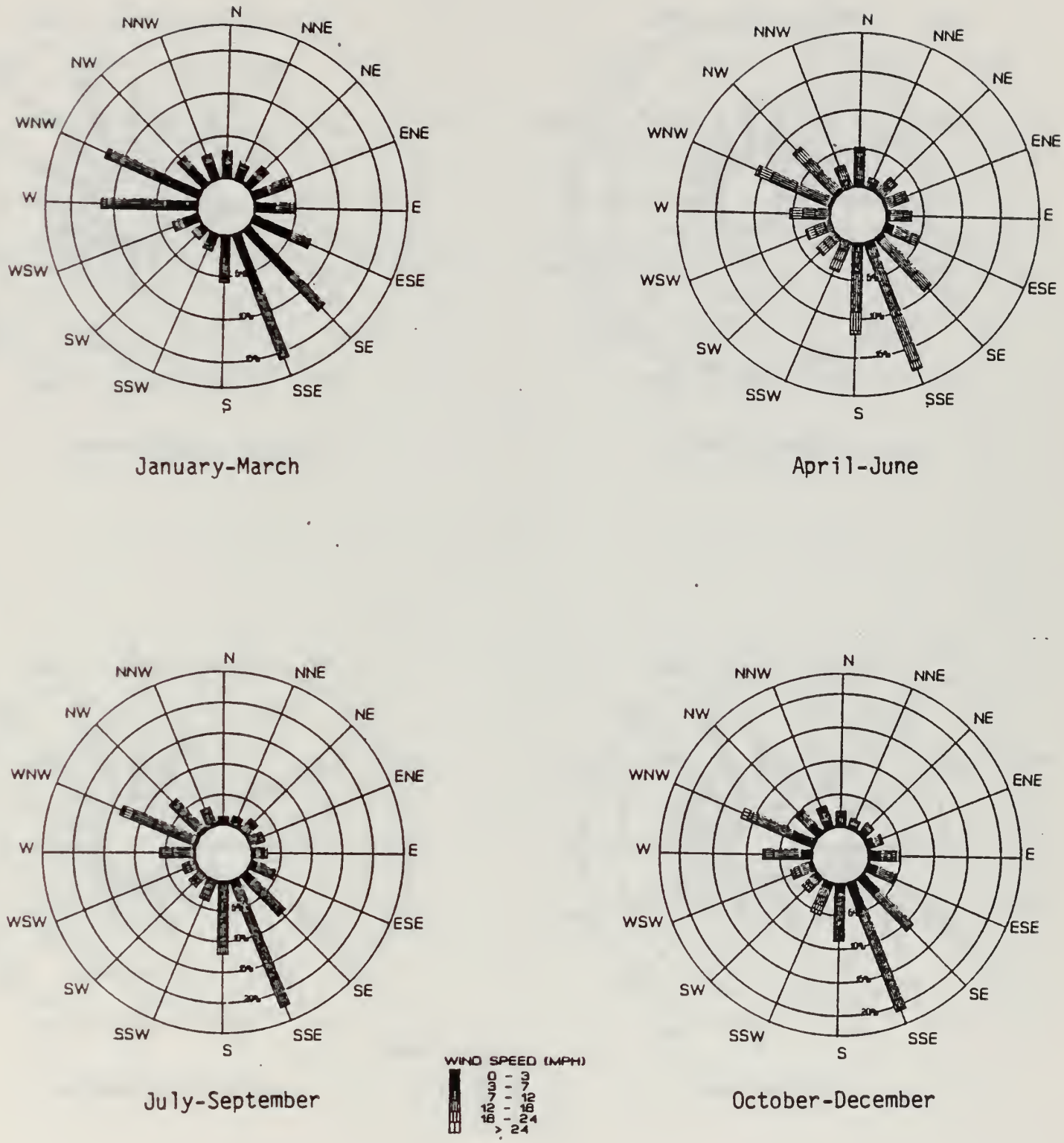


FIGURE 2.4-14. Seasonal wind roses for Site A6 in 1984.

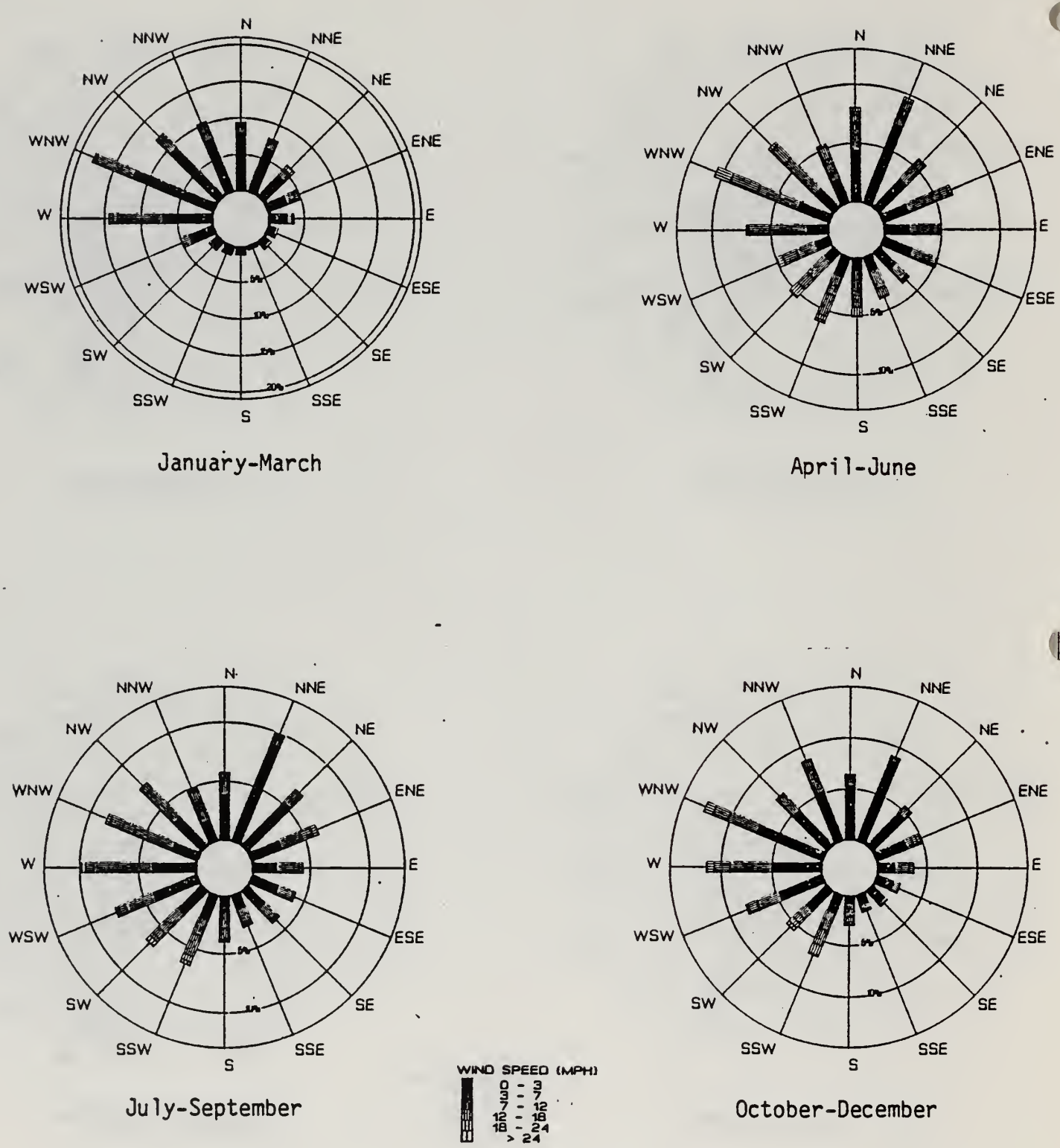


FIGURE 2.4-15. Seasonal wind roses for Site A10 in 1984.

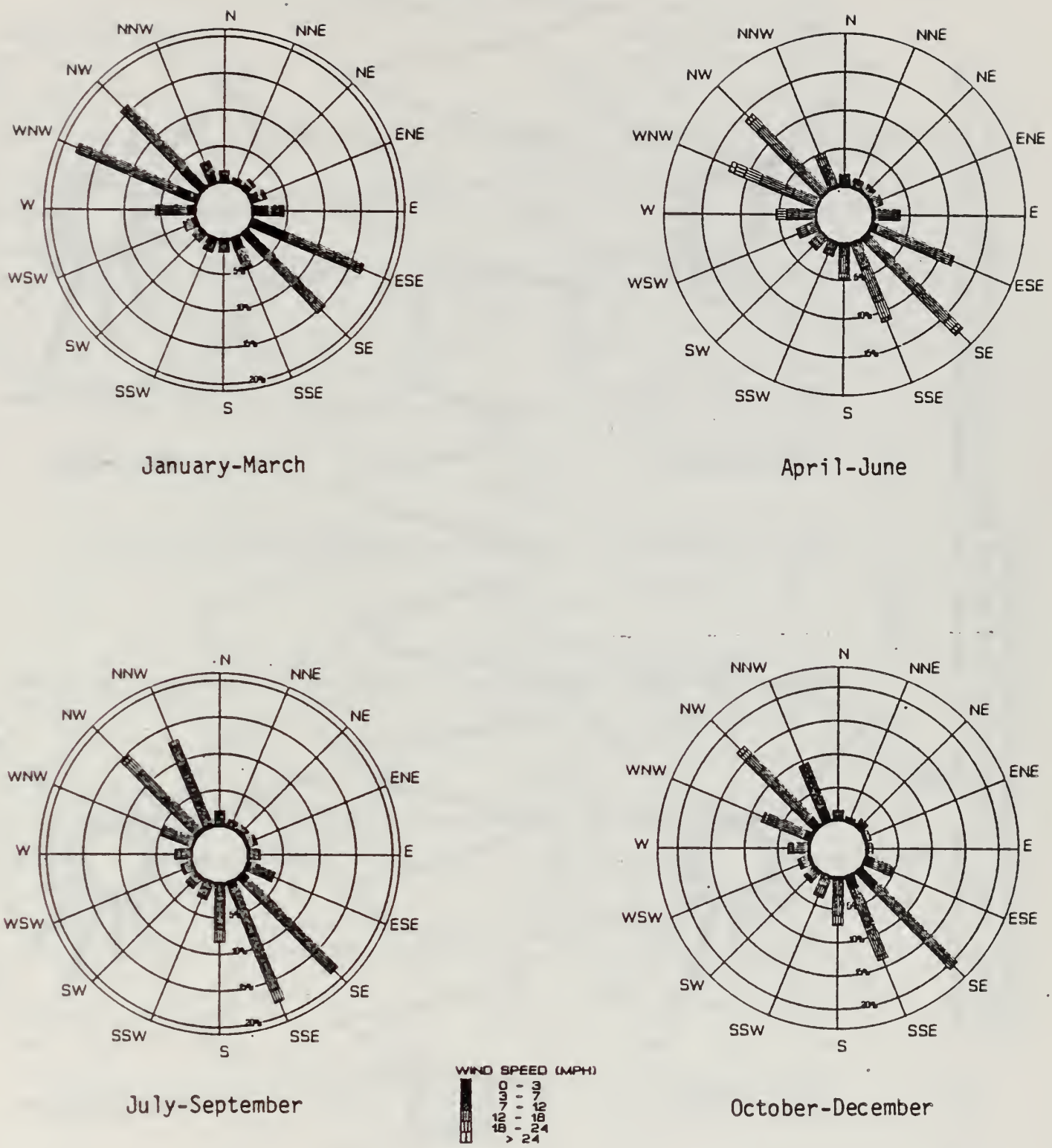


FIGURE 2.4-16. Seasonal wind roses for Site A11 in 1984.

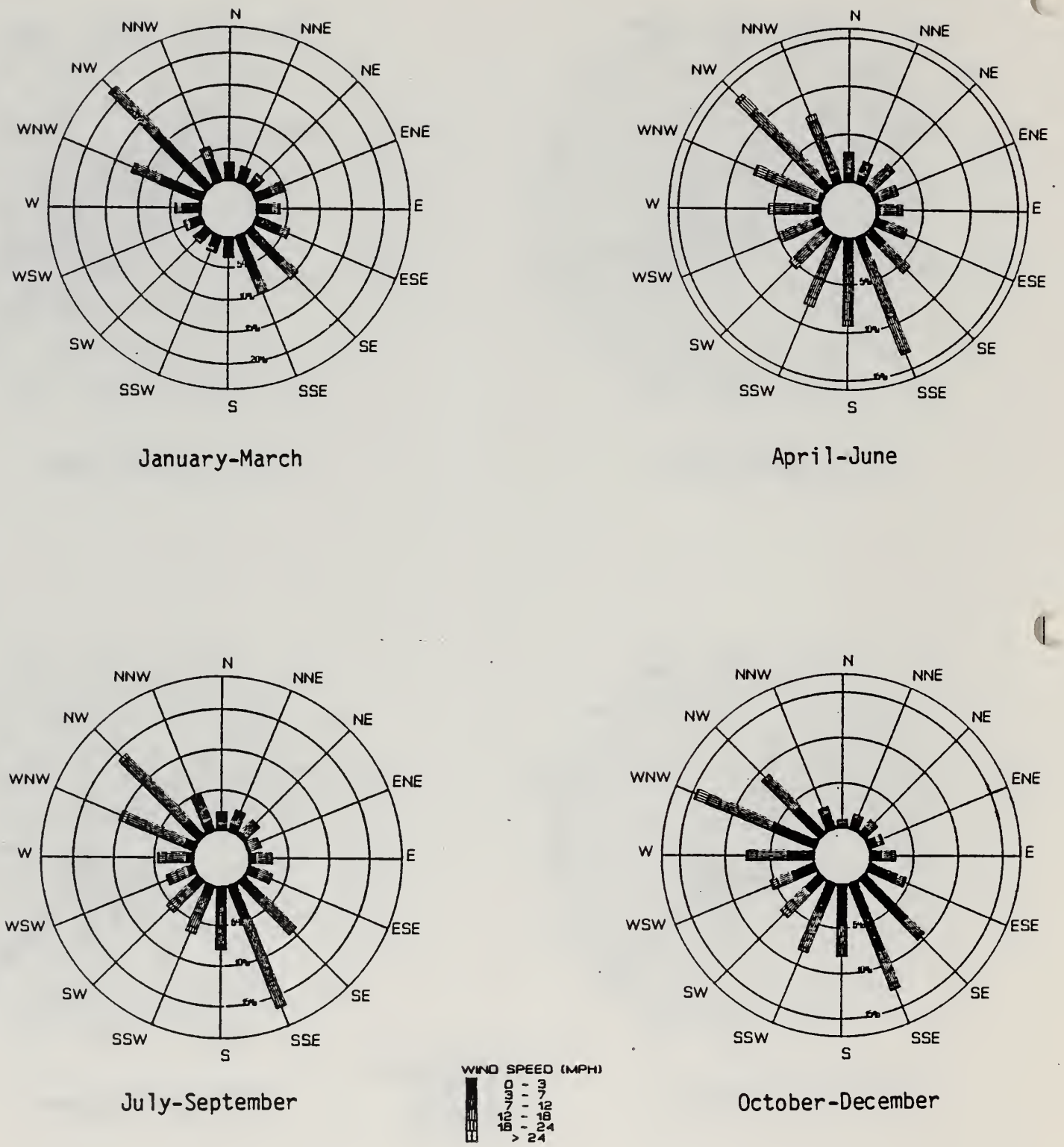


FIGURE 2.4-17. Seasonal wind roses for Site A13 in 1984.

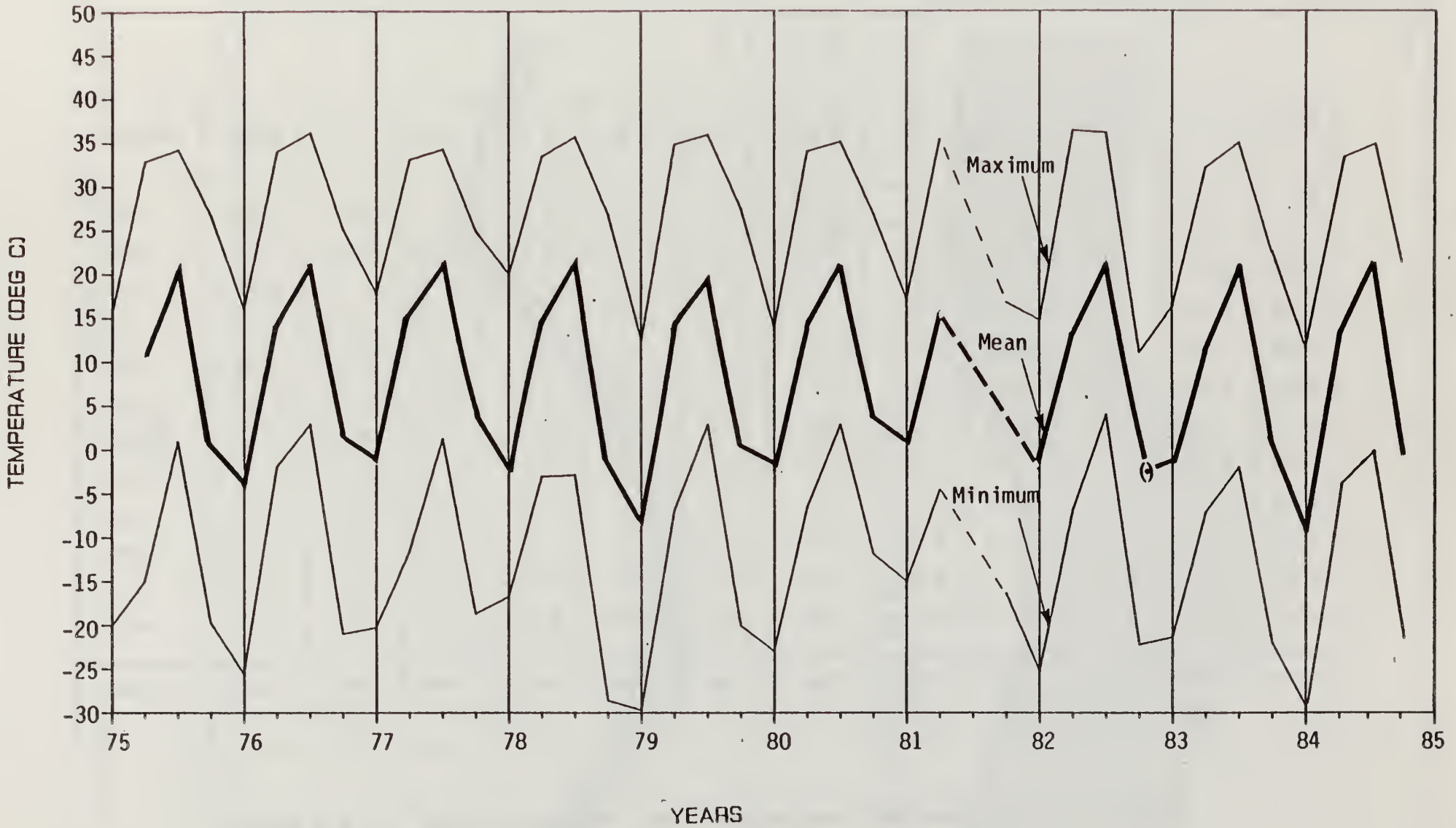
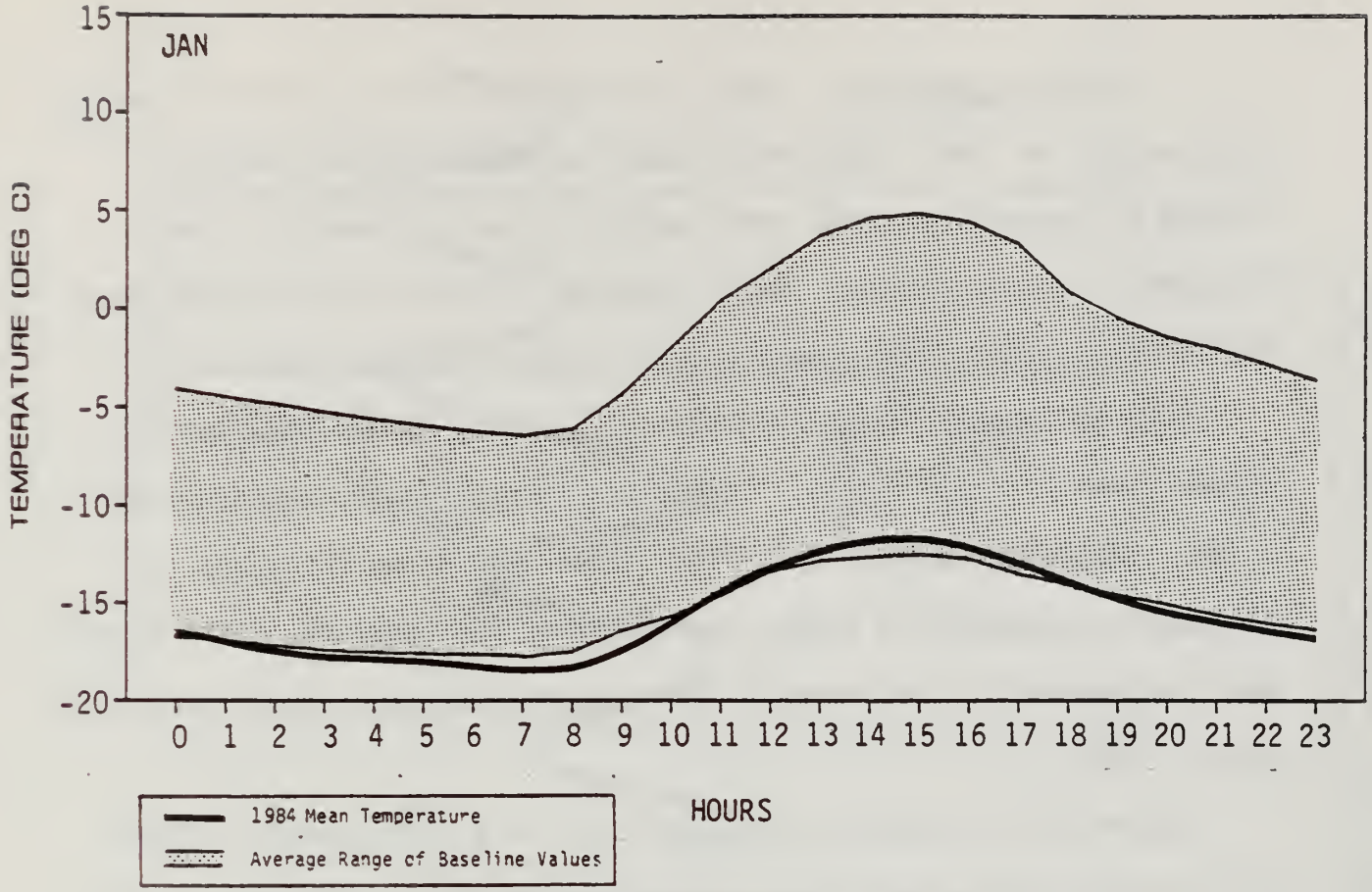


FIGURE 2.4-18. Seasonal maximum, mean, and minimum hourly temperatures (10 m) at A6 for 1975 through 1984. (•) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

TABLE 2.4-12. Monthly minimum, mean, and maximum temperatures (^{o}C) for 1984.

Month	A4			A6			A11			A13		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
JAN	-26.0	-13.5	-3.9	-29.9	-15.5	-5.0	-28.9	-15.9	-5.0	-27.3	-15.8	-1.9
FEB	-21.1	-9.0	0.1	-23.1	-12.0	0.7	-23.7	-11.8	0.7	-25.8	-12.4	3.4
MAR	-12.9	-0.5	10.9	-16.7	-1.1	11.4	-17.5	-2.4	11.1	-18.4	-1.1	12.2
APR	-5.2	6.5	23.1	-4.7	6.0	23.2	-7.0	5.0	24.6	-5.0	6.6	26.7
MAY	1.0	16.6	30.4	-2.9	15.5	31.3	-2.5	15.3	31.3	-2.2	17.4	34.2
JUN	3.7	18.6	33.0	2.0	17.7	33.1	-0.1	16.1	36.0	2.7	19.5	37.4
JUL	14.0	23.7	34.0	12.5	22.8	34.4	13.1	22.8	35.9	13.5	24.4	38.9
AUG	12.5	22.5	32.1	10.6	21.5	32.4	9.8	21.7	33.2	13.1	22.7	34.3
SEP	1.7	17.5	31.0	-0.1	16.4	31.4	-2.0	16.2	32.6	-2.5	16.8	33.1
OCT	-2.9	7.7	20.8	-4.7	7.2	21.2	-6.7	5.8	21.7	-6.3	6.8	23.0
NOV	-8.5	2.9	15.3	-14.8	1.0	15.3	-12.6	0.1	14.5	-17.1	0.0	15.1
DEC	-15.8	-5.0	7.5	-21.9	-7.5	7.9	-20.2	-8.2	6.6	-22.1	-7.9	7.6
Annual	-26.0	7.3	34.0	-29.9	6.0	34.4	-28.9	5.4	36.0	-27.3	6.4	38.9



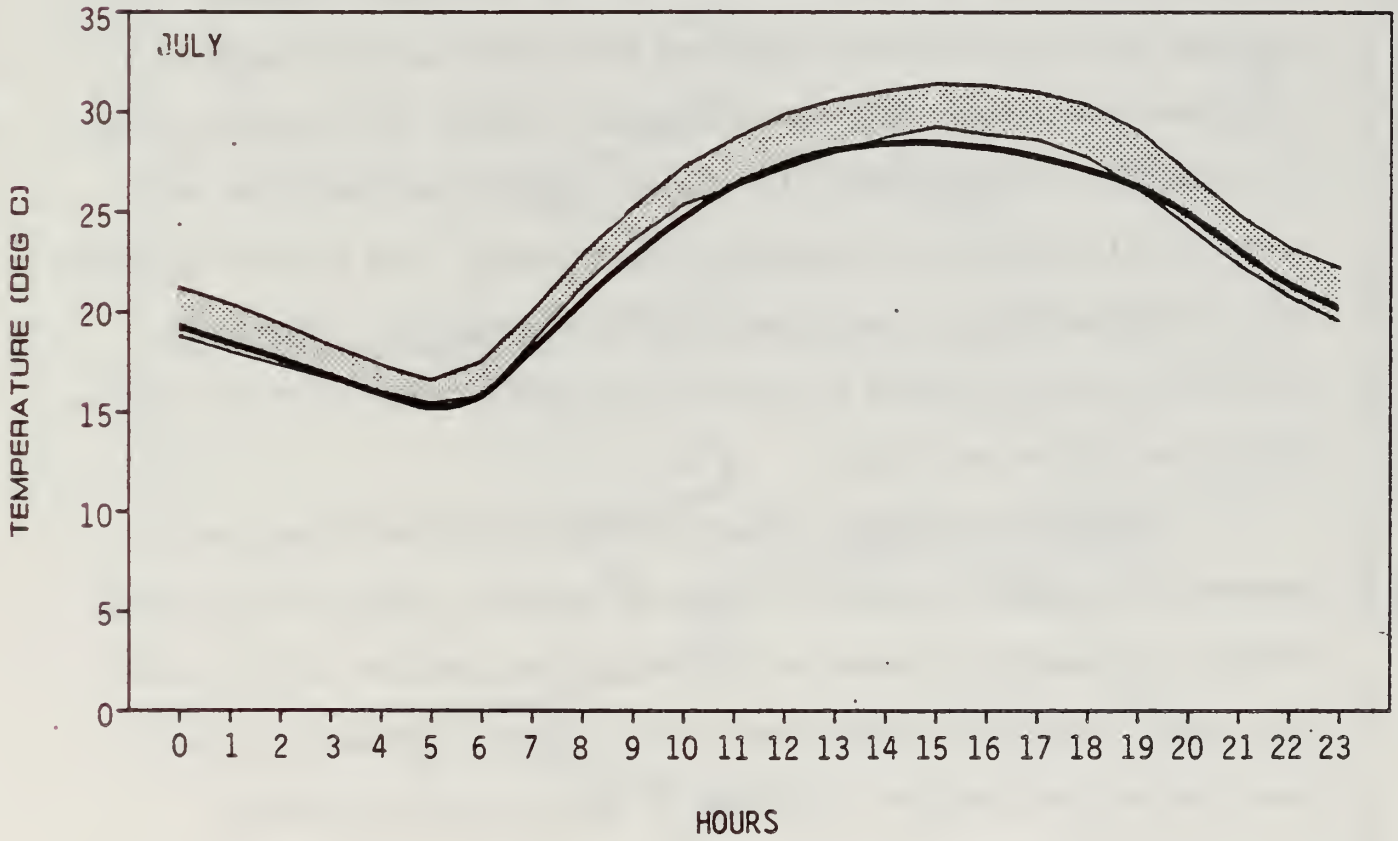


FIGURE 2.4-19. Monthly averaged January and July hourly temperatures (10 m) in 1984 versus baseline for Site A6.

C. Relative Humidity Figure 2.4-20 plots seasonal relative humidity for 1975 to 1984. Similar to 1983, the mean relative humidity in 1984 was generally higher than years previous to these last two. The 1984 year does show the normal seasonal distribution with the lowest humidities in spring and summer and the highest in winter and fall.

The 1984 monthly values of relative humidity versus baseline at A6 are given in Table 2.4-13. The values for the year range from 100% to 9%. The annual mean is 64%. This table also shows the means and minimums to be generally higher than those of the baseline. This difference corresponds to the somewhat lower temperatures and higher precipitation in 1984.

Figure 2.4-21 compares the January and July 1984 diurnal relative humidity distribution with the average baseline range of values. January recorded relative humidities that were within the baseline range, but along the upper edge. July had consistently higher than baseline relative humidity throughout the day, probably due to moisture from above normal precipitation from frequent thundershowers. The diurnal variation of relative humidity is approximately the reciprocal of temperature, indicating that the amount of moisture in the air remains fairly constant during the day on the tracts.

D. Barometric Pressure Figure 2.4-22 plots Site A6 seasonal barometric pressure for 1975 to 1984. In general, severe winter storms produce the lowest pressures and the basin high pressure cells produce the highest readings. During summer, the pressure systems that influence Utah are much weaker, resulting in fewer pressure extremes.

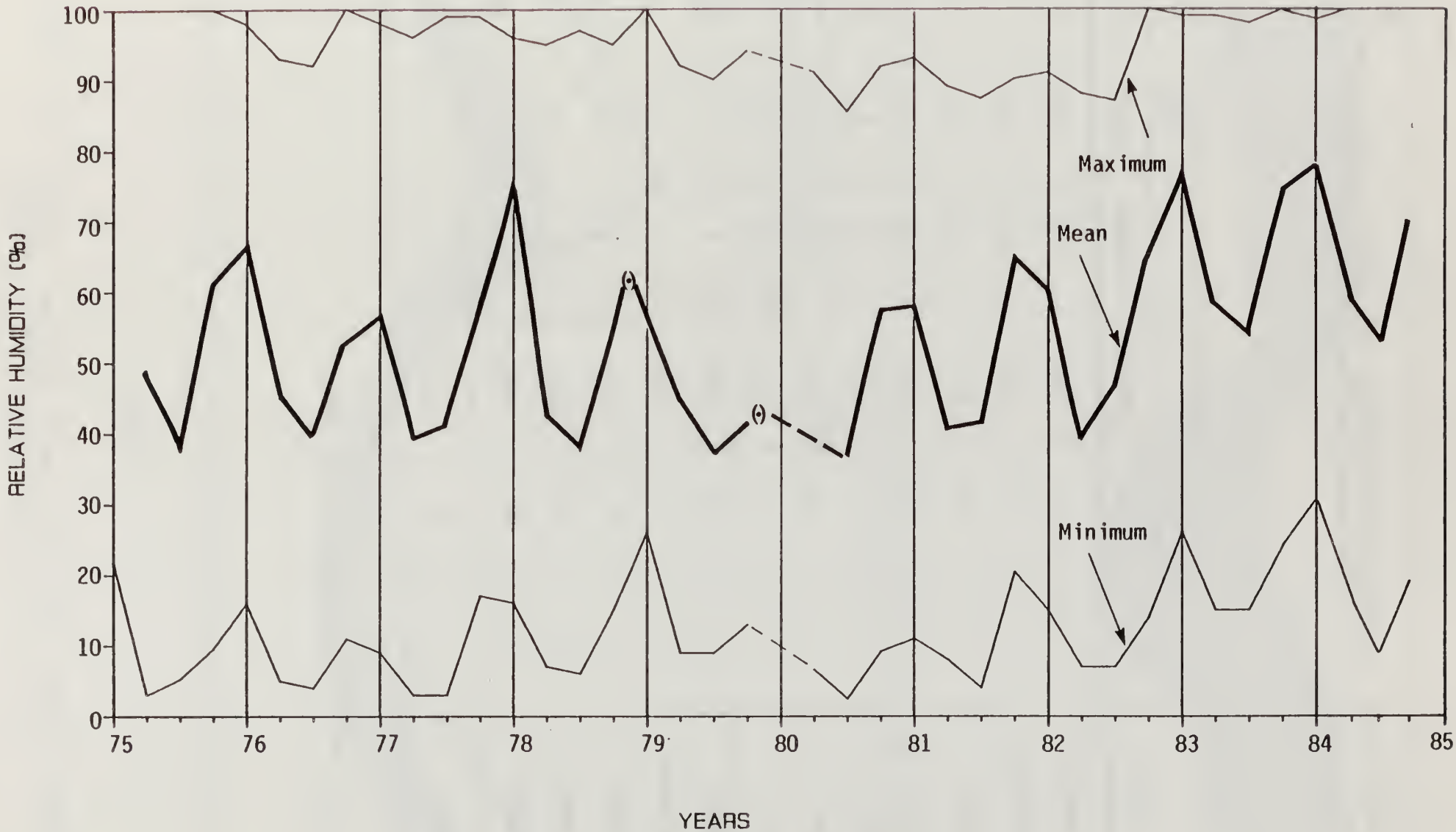


FIGURE 2.4-20. Seasonal maximum, mean, and minimum relative humidity for A6 for 1975 through 1984. (•) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

TABLE 2.4-13. Monthly minimum, mean, and maximum relative humidity (%) for 1984 versus baseline (1975-1981) at A6.

Month	Baseline			1984		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
January	18	72	100	50	80	96
February	9	65	100	43	78	96
March	10	60	100	30	74	98
April	3	47	100	20	61	99
May	5	47	100	18	53	96
June	4	34	100	(16)	(62)	(100)
July	3	37	100	(18)	(53)	(95)
August	4	39	100	9	52	100
September	9	43	100	14	51	100
October	9	51	100	19	59	100
November	15	60	100	25	66	100
December	11	68	100	(38)	(78)	(100)
Annual	3	52	100	9	64	100

() Less than 60% data recovery for month.

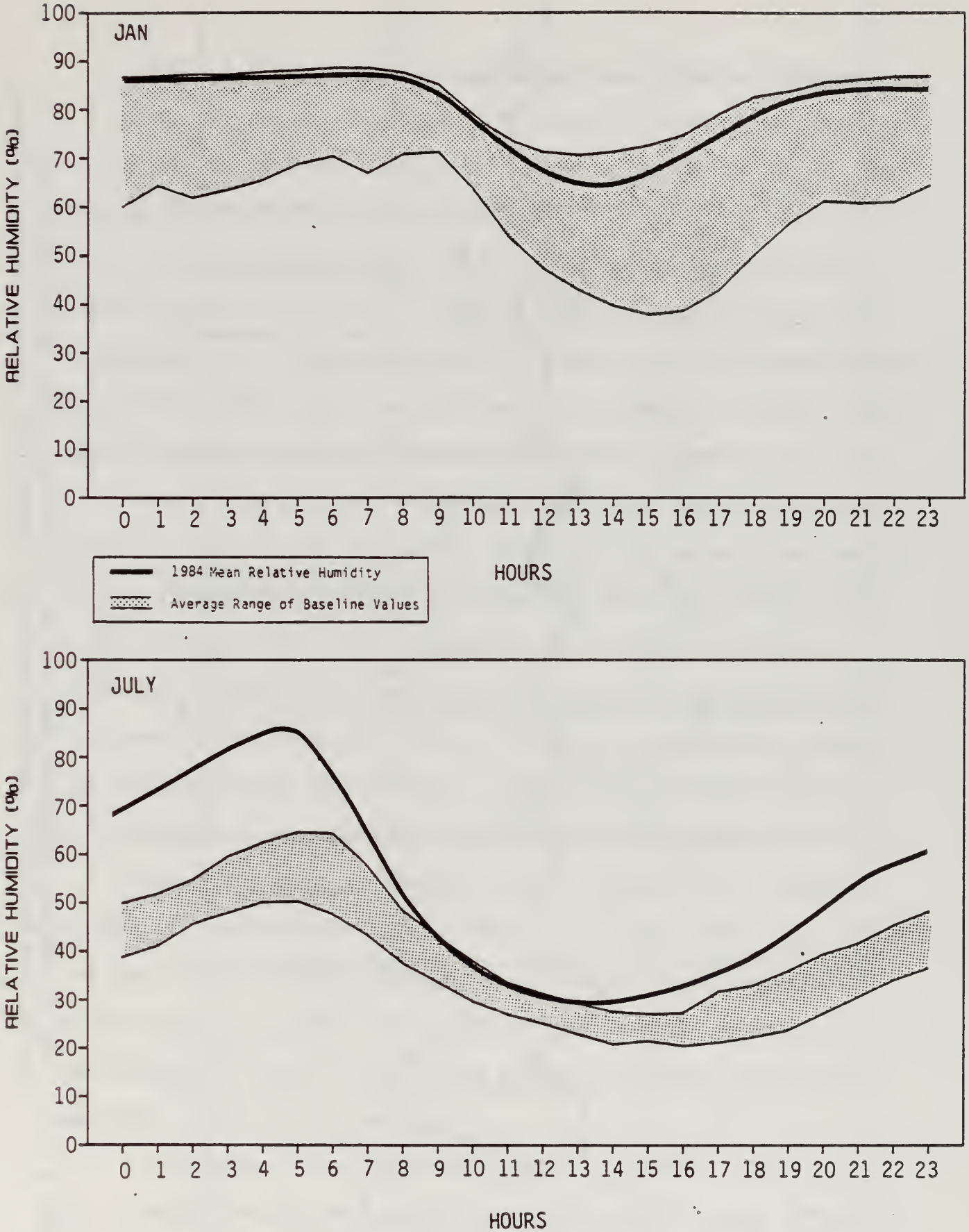


FIGURE 2.4-21. Monthly averaged January and July hourly relative humidity in 1984 versus baseline for Site A6.

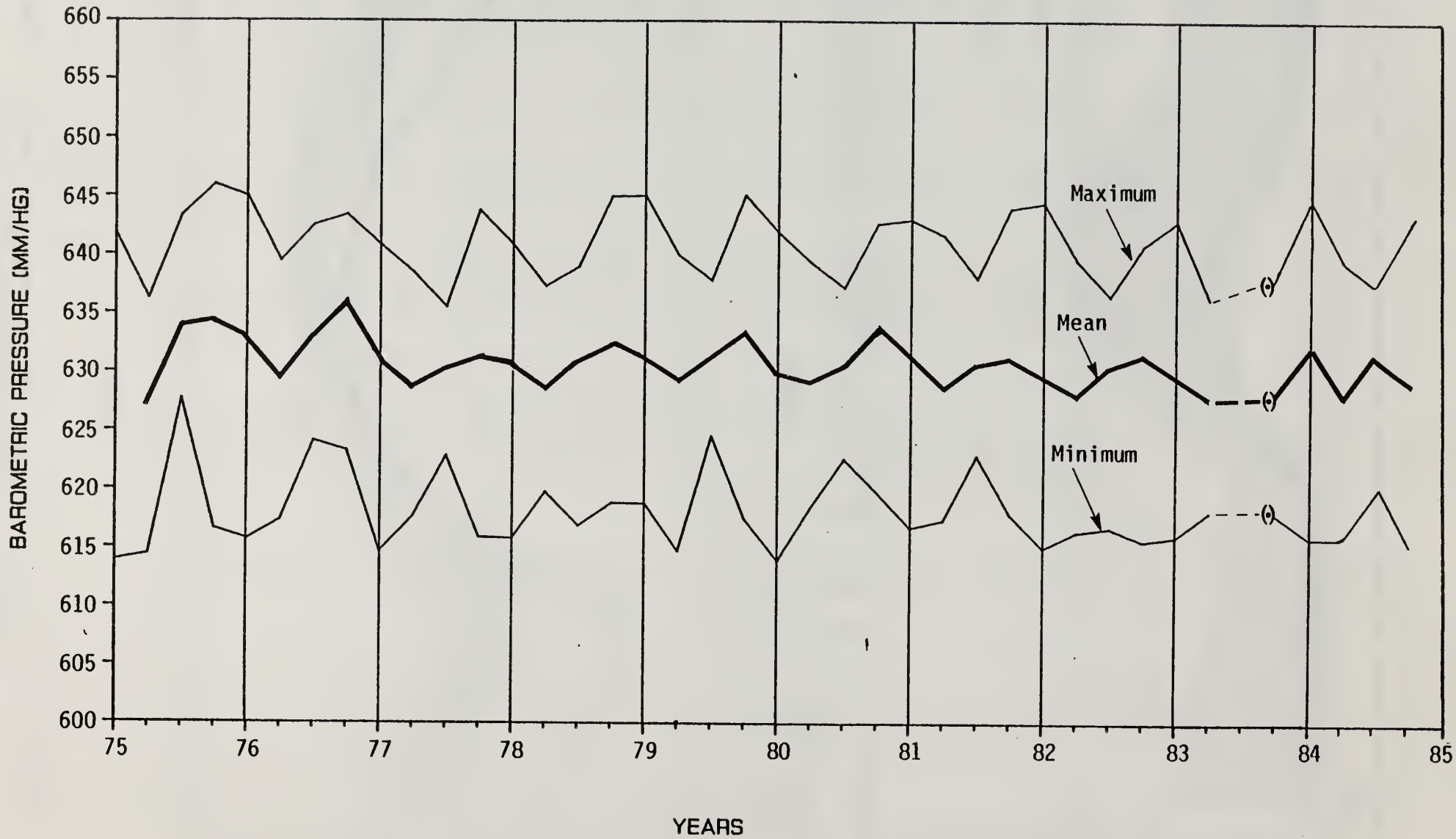


FIGURE 2.4-22. Site A6 seasonal barometric pressure for 1975 through 1984. (•) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

Table 2.4-14 lists Site A6 monthly averaged barometric pressure for 1984 and the baseline period. All values are within those observed in the baseline and show the typical pattern. The mean values in 1984 are very similar to the baseline means.

E. Net Thermal Radiation Figure 2.4-23 plots A6 diurnal net thermal radiation for January and July 1984 versus the baseline range. As expected, the radiation is higher in summer due to the longer periods of sunshine, more intense sunlight and less cloudiness. Highest values generally occur around noon when the sun is at its apex.

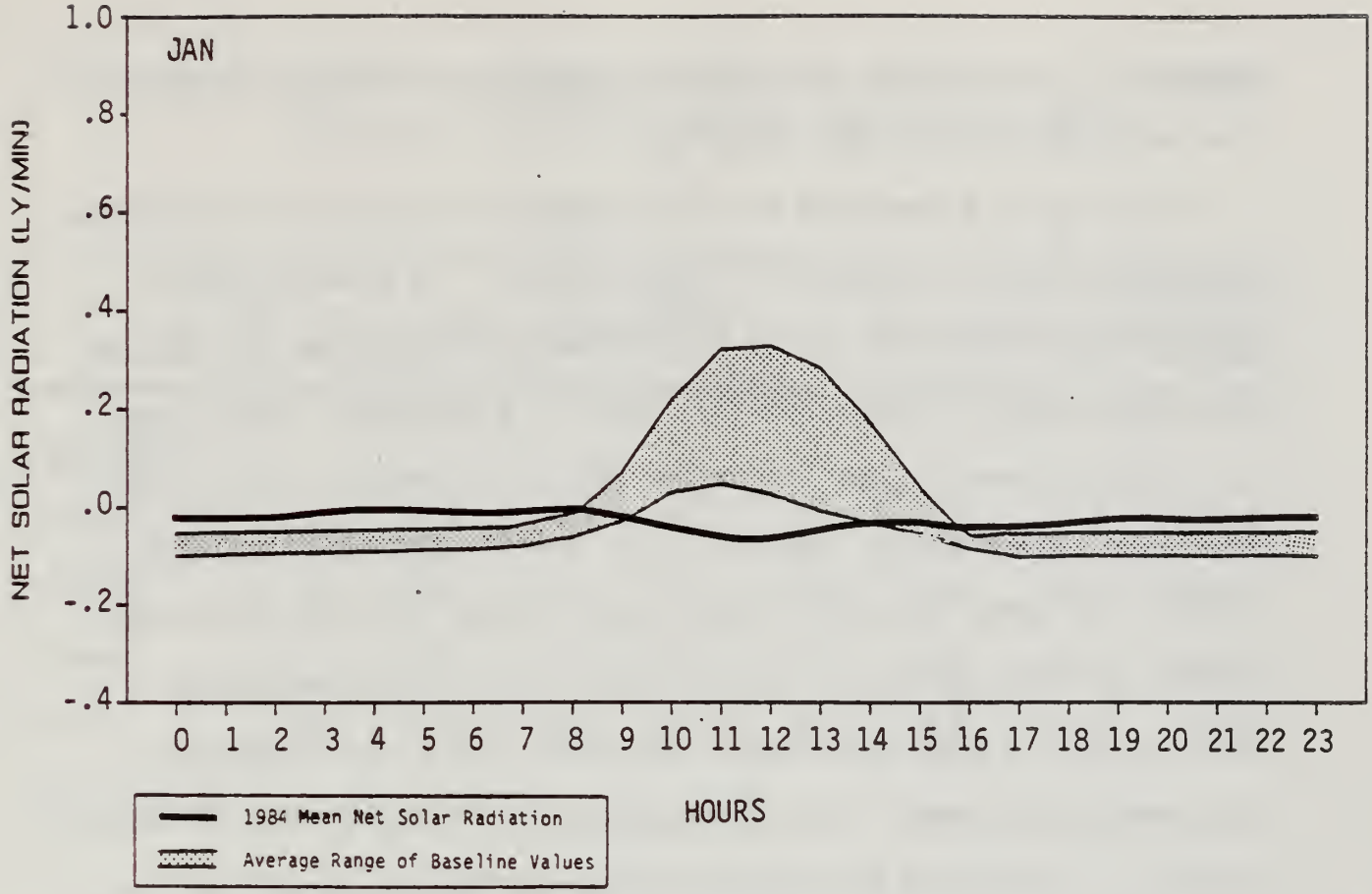
January midday values in 1984 were unusually low, and were often negative. As mentioned previously, this month had below normal temperatures with deep (8-12 inches) snow cover all month and frequent fogs due to the lower than normal wind speed and stagnation conditions. It was also necessary to frequently remove snow and ice covering the instrument during this time. It is likely that these factors caused the observations of net radiation loss even during daylight hours. July 1984 values generally fell within the baseline range.

2.4.2.3 Diffusivity When a pollutant in the form of a plume or puff is released into the atmosphere, it is transported by the prevailing wind. As it travels downwind, its concentration decreases as its volume increases. Its growth in the vertical is governed mainly by the atmospheric stability, while its growth in the horizontal depends upon both stability and turbulence.

A. Turbulence Mechanical turbulence is defined as the irregular and apparently random fluctuations in air velocities induced by surface

TABLE 2.4-14. Monthly minimum, mean and maximum barometric pressure (mm of Hg) for Site A6 for 1984 and baseline (1975-1981).

	Baseline			1984		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
January	614	632	645	626	635	644
February	616	632	645	620	632	640
March	614	628	641	616	629	636
April	614	629	642	616	626	639
May	616	628	638	622	629	639
June	616	629	640	620	629	635
July	623	631	638	625	631	636
August	623	631	640	620	630	637
September	617	632	643	625	631	636
October	617	632	643	619	628	637
November	616	633	646	617	630	637
December	617	633	645	615	630	643
Annual	614	631	646	615	630	644



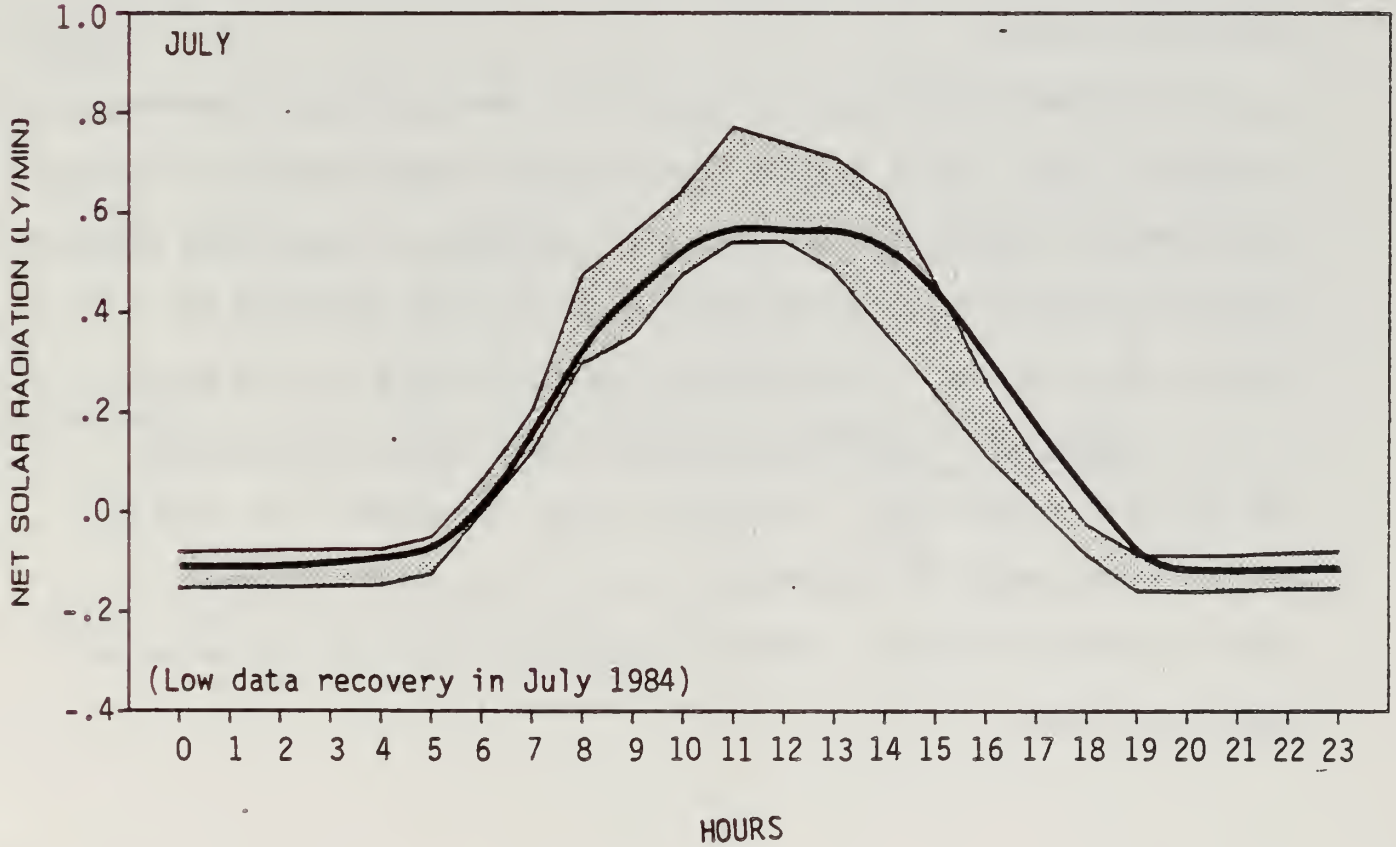


FIGURE 2.4-23. Monthly averaged January and July hourly net thermal radiation in 1984 versus baseline for Site A6.

roughness. An indicator of mechanical turbulence is the fluctuation of wind direction, or sigma theta (σ_θ).

Using σ_θ data from Site A6, the frequency distribution of different diffusion classes is computed in Table 2.4-15. The classification scheme used follows that in the Atomic Energy Safety Guide 23 (AEC, 1972) and appears in Table 2.4-16. During the baseline, stable cases (E, F, and G) were the most prevalent (36%), followed by neutral (D) conditions (35.6%), with unstable (A, B, and C) occurring the least (28.4%). In 1984, the pattern was similar except that the differences between the three groups are 66.1%, 24.0%, and 9.7%, respectively. Stable cases are more prevalent in the winter and fall, associated with lower wind speeds. The stable case value of 66.1% reflects the presence of the strong high pressure system which was present during the winter period.

The diurnal distribution of σ_θ at A6 in January and July appears in Figure 2.4-24. It is evident from the figure that both months had low values of sigma theta, and thus small variation in short-term wind direction, resulting in less fluctuation in the wind direction for January and July than in corresponding baseline months at Site A6.

B. <u>Stability</u> A complete dispersion picture must also include the effect of plume rise. The meteorological parameters that greatly influence the height of a plume are vertical atmospheric (thermal) stability and wind speed. Vertical atmospheric stability can be approximated by ΔT data.

TABLE 2.4-15. Relative frequency distribution (%) of diffusion classes using σ_θ at A6 during 1984 and the baseline period.

Season	Class							Total No. of Observations
	A	B	C	D	E	F	G	
1975-1981								
Winter	3.2	5.4	15.1	38.0	34.7	3.3	0.3	12,826
Spring	6.2	8.9	15.8	37.0	30.2	1.9	0.0	12,812
Summer	4.8	9.2	19.0	33.7	30.8	2.5	0.0	13,031
Fall	3.2	6.4	16.9	34.1	34.3	4.8	0.3	15,126
All seasons combined	4.3	7.4	16.7	35.6	32.6	3.2	0.2	53,795
1984								
Winter	0.0	0.0	1.6	22.7	59.3	14.2	2.2	2,179
Spring	0.2	1.2	8.3	24.1	33.5	16.6	16.2	1,841
Summer	0.4	3.8	11.1	25.6	35.1	16.9	7.1	1,585
Fall	0.9	4.8	9.9	24.0	37.1	17.5	5.8	1,610
All seasons combined	0.3	2.2	7.2	24.0	42.4	16.1	7.6	7,215

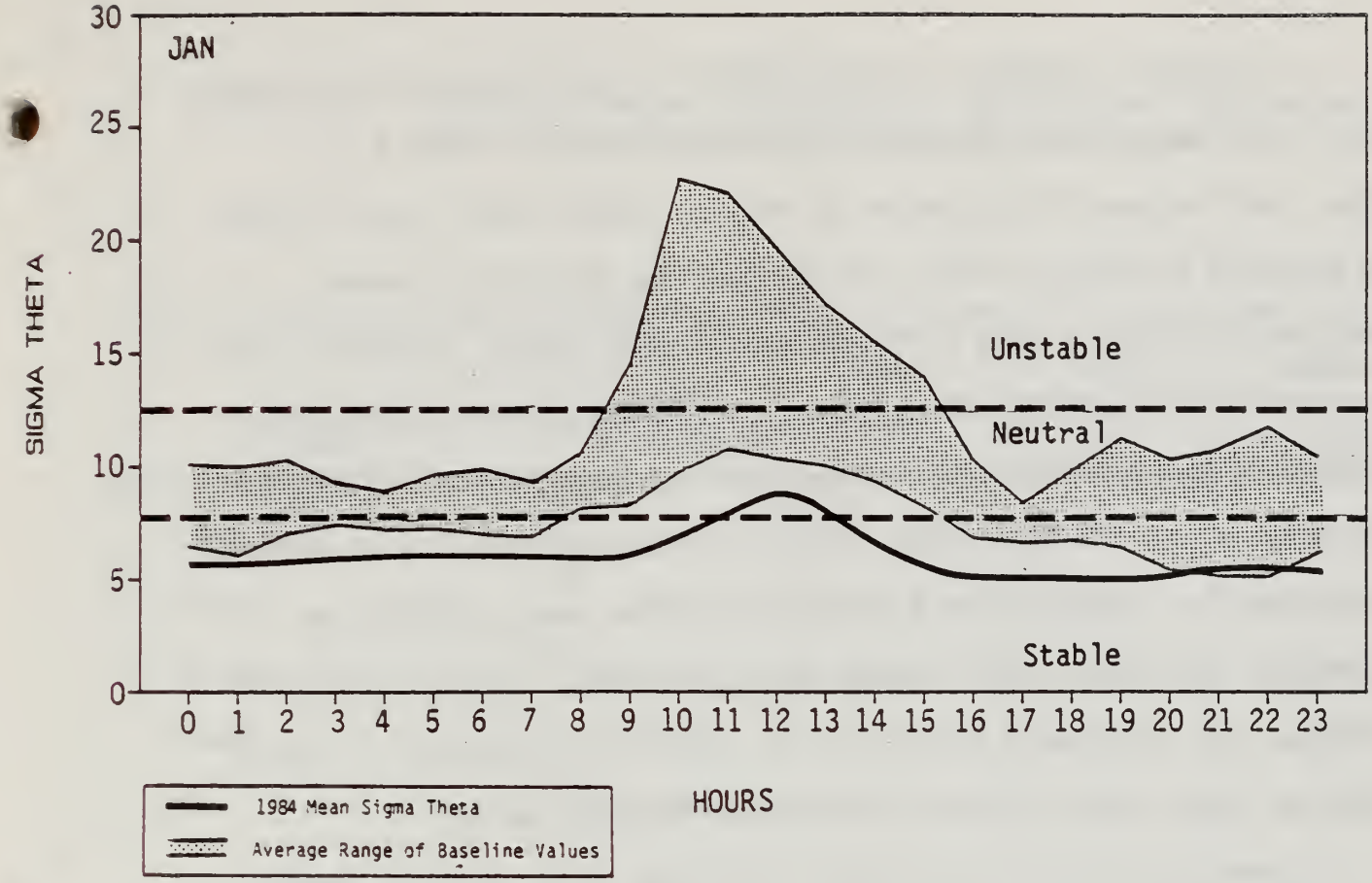
NOTE: Table 2.4-16 defines classes A-G.

TABLE 2.4-16. Classification of atmospheric diffusivity using σ_θ.

Stability Classification	Pasquill Categories	σ_θ* (Degrees)
Extremely unstable	A	>22.5
Moderately unstable	B	17.5-22.5
Slightly unstable	C	12.5-17.5
Neutral	D	7.5-12.5
Slightly stable	E	3.5-7.5
Moderately or very stable	F	2.0-3.5
Extremely stable	G	0-2.0

Source: Atomic Energy Safety Guide 23 (AEC, 1972).

*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to one hour.



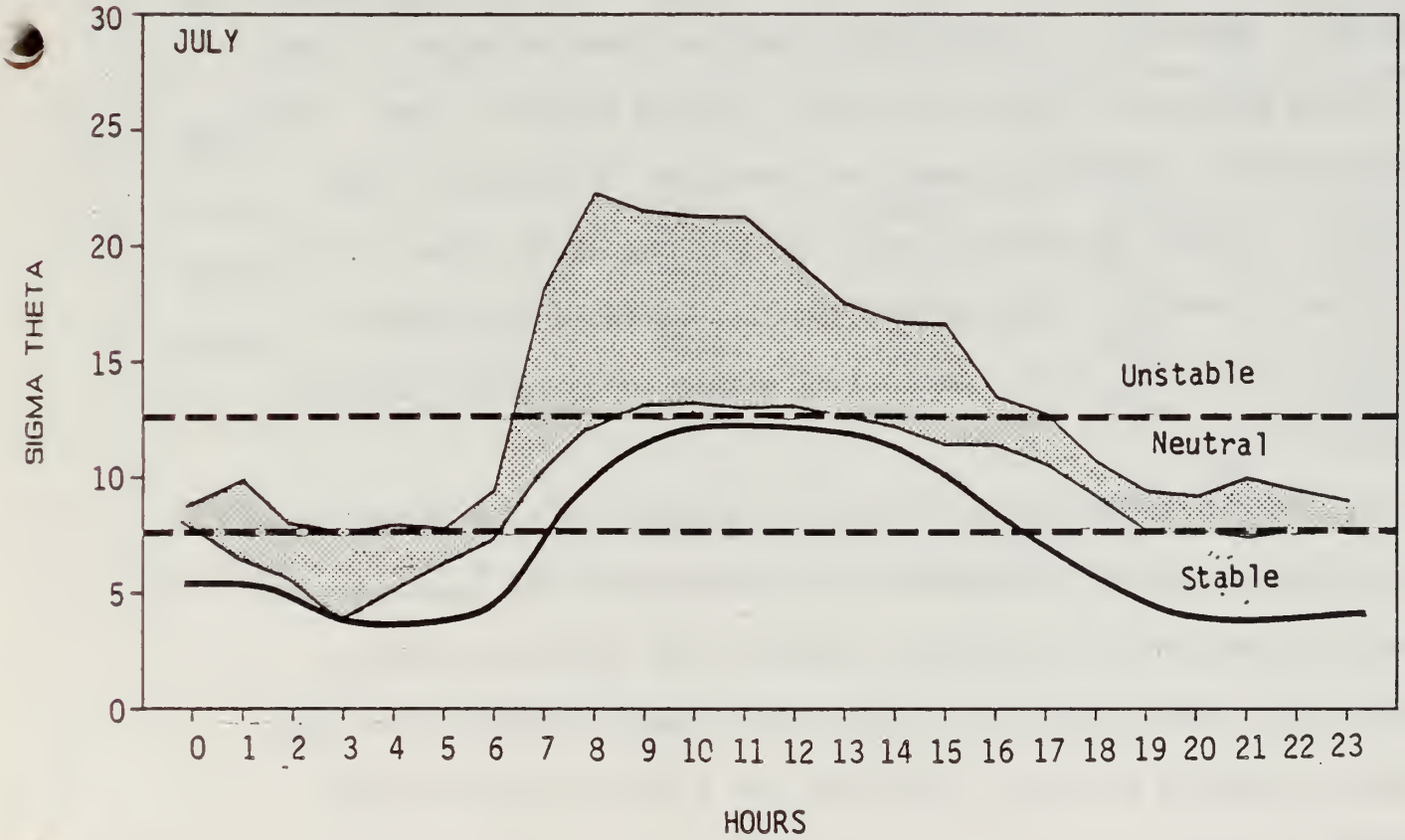


FIGURE 2.4-24. Diurnal distribution of σ_θ at Site A6 for January and July 1984 versus baseline.

In equations derived by Briggs (1974) for calculating plume height, only three atmospheric stability classes are needed. Table 2.4-17 shows the frequency distribution of each of these three classes, based on seasonal ΔT data for both 1984 and baseline ΔT data by season. The classification scheme for these stabilities follows in Table 2.4-18.

Using this classification method, all three classes occur approximately one third of the time in the baseline, but the neutral/unstable category is only 33.7% in 1984. While the 1984 σ_θ data show more stability due to less turbulence, the ΔT data show less stability due to weaker inversions and/or better mixing in 1984. Like the diffusion classes, the very stable cases usually occur most frequently in the fall and winter, when stronger inversions generally exist.

Figure 2.4-25 shows the diurnal variation of ΔT at A6 in January and July. Generally, a temperature inversion forms at night, as the air cools more quickly than the ground, leaving a stable layer. Warming during the day eventually breaks the inversion, allowing for freer mixing. In July, the warming occurs earlier and lasts later into the day than in January, allowing more time for unstable conditions to take over. In 1984, the ΔT means fall within the baseline range of values.

C. <u>Pollution Potential</u> The diffusion data are significant because the stable situations are generally associated with the lowest dispersion, and hence have the greatest potential for pollution impacts. Since stable conditions occur in the tracts more than 30% of the time (whether based on ΔT or σ_θ), this area has a fairly high pollution potential.

TABLE 2.4-17. Relative frequency distribution (%) of stability classes using ΔT at A6 during 1984 and the baseline period.

Season	Unstable or Neutral <-0.1/20 m	Slightly Stable -0.1-0.3/ 20 m	Very Stable >0.3/ 20 m	Total Number of Observations
1975-1981				
Winter	39.0	25.7	35.3	14,578
Spring	44.4	29.8	25.8	14,745
Summer	37.4	30.0	32.6	13,233
Fall	37.8	22.8	39.4	14,633
All seasons combined	39.7	27.0	33.3	57,189
1984				
Winter	39.3	25.8	34.8	2,178
Spring	58.0	19.8	22.1	2,182
Summer	45.8	27.8	26.4	2,197
Fall	47.3	21.1	31.6	2,208
All seasons combined	47.7	23.4	28.8	8,765

TABLE 2.4-18. Classification of atmospheric stability using ΔT.

Stability	ΔT ($^{o}C/100$ m)
Unstable and Neutral	<-0.5
Slightly Stable	-0.5 to 1.5
Very Stable	>1.5

Source: Briggs, 1974.

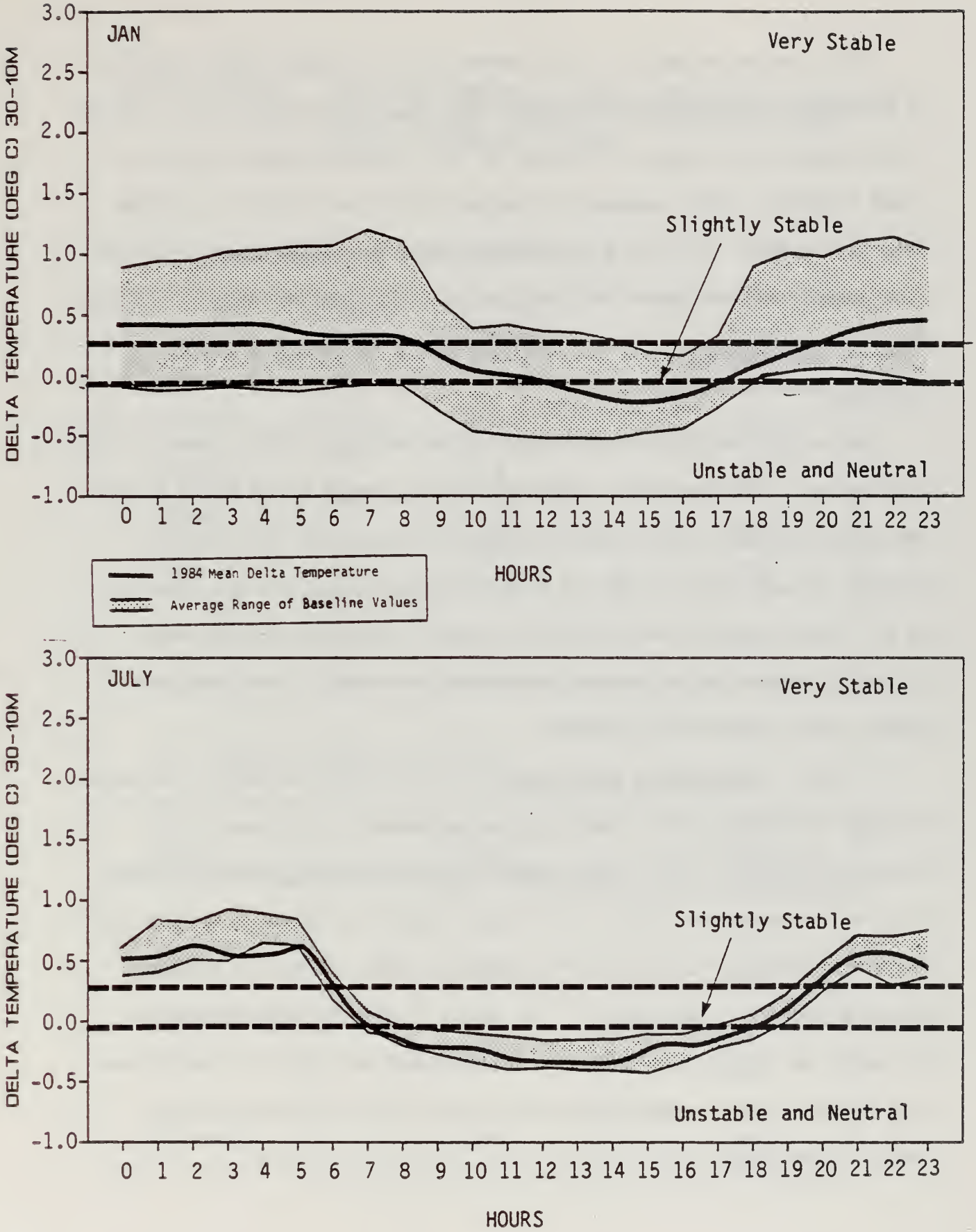


FIGURE 2.4-25. Diurnal variation of ΔT at Site A6 for January and July 1984 versus baseline.

As a further measure of this potential, pollutants tend to build up even more under stable conditions when the wind speed is low. Table 2.4-19 shows the seasonal frequency of the combined stable/low wind speed factors. When compared to Tables 2.4-15 and 2.4-17, it can be seen that almost all of the very stable cases are associated with low wind speeds. The highest frequency of this combination occurs in winter, meaning the possibility of air quality impact during this season is greatest.

Low winds and stable conditions occur mostly at night, when drainage wind patterns are prevalent. For the tracts, these winds would carry the emissions down the drainage valleys and along the White River. Station A10 was sited along the river to detect any of these impacts. So far, most construction activities occur during the daytime when mixing is better, so no impacts have been observed. Once operation begins, this pattern may change.

2.4.2.4 Atmospheric Data Summary Table 2.4-20 presents the annual averages of each of the meteorological parameters discussed in the previous sections. This table summarizes the means of these data for each of the years monitored. As with air quality, there is only slight variation from year to year in the overall means, with no definite patterns among the parameters. The annual averages show 1984 to be not quite as unusual as 1983, but still characterized by slightly lower wind speeds, lower temperatures and higher relative humidities than those in the baseline.

TABLE 2.4-19. Relative frequency of low wind speed (<3.5 m/s) combined with very stable atmospheric conditions in 1984 at Site A6.

a. Stability based on $\Delta T > 1.5^{o}C/100$ m

Season	Frequency (%)	Total Observations
Winter	34.7	755
Spring	16.6	363
Summer	24.4	537
Fall	31.1	687
All year	26.7	2,342

b. Stability based on $\sigma_\theta \leq 3.5$

Season	Frequency (%)	Total Observations
Winter	7.3	159
Spring	6.4	118
Summer	2.7	43
Fall	6.4	103
All year	5.9	423

TABLE 2.4-20. Annual averages of the meteorological parameters measured during the entire monitoring period at A6.

	Wind Speed (10 m) (mph)	Temperature (10 m) (°C)	Relative Humidity (%)	Barometric Pressure (mm HG)	Solar Radiation (ly/min)	ΔT (30-10 m)	σ_θ (30 m)
1975	8.9	8.3	52.6	631	(0.07)	0.67	(--)
1976	9.4	8.1	51.1	633	0.09	0.01	9.0
1977	6.9	9.8	48.9	630	0.08	0.14	10.2
1978	6.3	7.8	51.2	631	0.06	0.14	10.0
1979	6.5	6.3	(61.0)	631	(-0.05)	0.16	10.8
1980	6.9	9.1	(45.0)	631	0.03	0.09	12.1
1981	6.5	(6.2)	51.2	630	0.06	(0.14)	10.9
1982	6.0	8.2	52.4	630	-0.05	0.14	9.0
1983	4.9	8.1	66.0	(628)	0.07	0.04	7.5
1984	5.5	6.0	64.0	630	0.08	0.10	6.0

() Average based on data of insufficient quantity to meet EPA (1977) criteria.

-- Low data recovery.

2.4.3 Sound Levels

Peak and average quarterly sound levels for 1984 are shown in Table 2.4-21. Sound level measurements in 1984 show that site A4 had the lowest sound levels ($\leq$32 dB(A)); sites A6 and A10 had slightly higher levels ($\leq$45 dB(A)); and levels along the roadway (Highway 45 and Ignacio) are the highest ($\leq$53 dB(A)). (No noise levels were monitored at Asphalt Wash site in 1984, the previously quietest site during 1982-1983.) Noise was fairly constant during the two 84 seasons (monitoring was done in winter and spring only) monitored at these sites, similar to the past years.

Most background noise on the tracts is from natural sources -- insects, rustling grass, birds and wind -- and the noise level from these is somewhat variable. Another natural source, which affects certain areas, is running water in the White River. Noise from the White River construction activities, Gilsonite mine operation, aircraft passing over and traffic along the roads adds to this background, usually in the range of 5-20 dB(A).

The peak reading in 1984 was 53 dB(A) at the Ignacio site. This site is near the White River and close to the road where construction and other traffic passes. The average readings in 1984 ranged from 20-36 dB(A), which is typical of rural background sound levels. For the most part, peak levels monitored in 1984 are slightly higher than those from 1983 but lower than 1982. Average values were very similar for all year's monitored (including baseline measurements made in 1975).

TABLE 2.4-21. Summary of quarterly peak and average sound level data for 1984.

Site	Quarterly Readings			
	Peak Sound Levels (dB(A))		Average Sound Levels (dB(A))	
	1st	2nd	1st	2nd
1. Highway 45 (a.m.)	43	45	29	≤27
(p.m.)	47	50	30	≤31
2. Ignacio (a.m.)	50	45	35	32
(p.m.)	53	50	36	34
3. Site A4	32	30	≤24	≤24
4. Site A6	36	45	≤29	≤28
5. Site A10	45	37	≤34	≤29
No. Readings/Site	12*	11	12*	11

*Site A10 had only eight readings due to weather.

(≤)Averages contain readings of 20 dB(A) at the lower end of the instrument's scale.

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3.0 VEGETATION RESOURCES

3.0 VEGETATION RESOURCES

3.1 INTRODUCTION

The following section discusses the vegetation monitoring studies conducted during 1984 which incorporates data from the 1974-1976 baseline studies with the data collected on Tracts Ua and Ub since that time. There has been a concerted effort to document existing conditions and determine interactions between the vegetation and abiotic and biotic factors on the tracts. The vegetation monitoring program affords two important advantages:

- o documentation of vegetation responses to natural fluctuation or variation, that could otherwise be interpreted as impacts of development, and
- o identification of problems early before they become serious, enabling corrective measures or contingencies to be initiated prior to any irreversible environmental change.

The vegetation monitoring program is also designed to provide data that describe the possible effects on the vegetation community caused by oil shale mining, processing and disposal of the retorted shale. The array of vegetation-related parameter used in monitoring includes key vegetation-related characteristics that are vital to ecosystem function. The characteristics are sensitive to immediate impacts of development or to cumulative influences plus interactions with affected ecosystem processes. The monitoring program includes variables that are indicative of environmental health and responsive to environmental impact.

3.2 SUMMARY

The vegetation monitoring program was composed of seven interrelated tasks that are designed to document existing conditions, determine and quantify interaction between the vegetation and abiotic and biotic factors, and provide a means of identification of impacts on the vegetation by development. A summary of the results for 1984 for each of those seven components follows.

3.2.1 Production of Annual Plant Biomass

Production of annual plant biomass was quite low in 1984 with the total of all four community types averaging only 25.2 oven-dried g/m^2 compared to 64.6 g/m^2 in 1983. The riparian vegetation type again had the highest biomass and cover of the four vegetation types considered averaging 70.5 g/m^2 and 21.3%, respectively. The juniper type had the lowest biomass and cover averaging 0.5 g/m^2 and 0.2%, respectively. The shadscale type averaged 17.5 g/m^2 for production and 10.0% for cover, while the sagebrush-greasewood areas averaged 12.4 g/m^2 for production and 6.4% cover. Precipitation records were compared with annual plant biomass data. Annual plant biomass is positively correlated with the sum of January, April, and May precipitation. Despite 1984 having an overall high precipitation regime, May precipitation was low and may have caused the reduction in biomass because of the dependence of annual plant biomass to spring precipitation.

3.2.2 Sagebrush Leader Growth

Over the ten years of study, sagebrush mean stem growth has ranged from a low of 2.7 cm in 1977 to a high of 8.4 cm in 1979. The data for 1984 on mean sagebrush leader growth (7.6 cm) was the second highest value recorded

during the study period. An analysis of variance (ANOVA) was performed on the data (Sites 1-6) for the ten years of record. The results point out that there was a significant difference in mean leader growth between years. An ANOVA test comparing study sites on tract also showed significant differences. Site 3 had the longest stem lengths while site 5 had the shortest.

Growing conditions for sagebrush in 1984 were very good and this was reflected in the increased leader growth. Leader growth for all ten sample years (1975-1984) is positively correlated with December through March precipitation. The precipitation for the 1984 winter period averaged 9.60 cm which was the third highest average recorded (1979 was highest with 10.85 cm).

3.2.3 Litterfall Measurements

A total of 242 litter traps were placed underneath seven dominant species of shrubs and trees, at location scattered throughout the tracts, to assess the amount of biomass returning to soil. The data on litterfall will serve as baseline by providing information on nutrients returning to the soil and food resources to many small animals. Litterfall was highest (on a weight per size index or volume) for shadscale at 316.6 g/m^3. Sagebrush averaged 185.1 g/m^3, followed by greasewood (97.0 g/m^3, spiny hopsage (79.7 g/m^3), fourwing saltbush (71.3 g/m^3) and rabbitbrush (39.4 g/m^3). Juniper litter traps were not equivalent to those traps used for the six shrub species and should not be compared with litterfall from these species. Litterfall under juniper was greater in 1984 (225 g/m^2) compared to 1981 (123 g/m^2), and 1982 (112 g/m^2) or 1983 (54 g/m^2) levels for the June to October sampling period.

3.2.4 Assessment of Animal Utilization of Plants

Animal use of shrubs was assessed using the Cole Browse Survey at six sites utilizing three key forage species. June 1984 data showed that shadscale leader growth was browsed (6%) less than sagebrush (42%) and greasewood (71%). This pattern was very different than that of 1983 when shadscale had the highest utilization. In addition to the Cole Browse Survey Method to assess browse useage, 20 sagebrush plants were enclosed with chicken wire at two sites, VG1 and SLG6. These caged and noncaged plants were measured for leader length to obtain estimates of actual biomass taken by browsing animals. Results showed significant difference between caged and uncaged shrubs indicating that browsing of sagebrush during this period was fairly intense particularly at site VG1.

3.2.5 Lichen Monitoring

During the 1982 field season, 21 permanent stands were located along three transects radiating from the proposed plant site. At each stand a permanent photo plot was established and a 20 m transect was permanently marked from which cover and frequency data were taken. The plots were revisited in 1983 and 1984; permanent photo plots were photographed to ocularly document baseline conditions, total lichen cover was estimated, the frequency of each species recorded, and the number of lichen species occurring in each quadrat was determined. From the results of the 1983 lichen monitoring program, total cryptogamic cover, number of lichen species/quadrat and frequency of the most prevalent lichen species at each stand were found to be good parameters for measuring current conditions and valuable for monitoring future impacts.

The results of the 1984 lichen monitoring program completes the baseline

characterization of the saxicolous lichen communities at 21 stands located at incremental distances from the plant site along 3 different transects. The lichen monitoring program was further refined in 1984 by recording the frequency of the most prevalent species at each stand. The eight most prevalent species identified in 1983 were selected by averaging species frequencies over all 18 stands. The 1984 lichen frequency estimates for two lichen species was slightly higher than the two previous years. The moist conditions that existed during the field sampling period aided field observers in distinguishing these species from others and from rock surfaces.The frequency of two other species was slightly lower in 1984 which is probably explained by the taxonomic confusion with other species due to their wide morphological range of characteristics. The frequency of the other most prevalent species did not change significantly from year to year. Total lichen cover estimates in 1984 varied from previous year's estimates at only three stands. The average number of saxicolous lichen species encountered in each quadrat was higher at four stands and lower at one stand in 1984 as compared to the previous two sampling years.

3.2.6 Soil Microbiology and Soil Chemistry

Samples were taken along transects at eight sites within the four vegetation types recognized on the tracts. The sites were sampled quarterly (January, April, July, October) in 1984 to assess yearly fluctuations. Soil moisture content fluctuated from a high in January of 24.3 to a July low of 6.9. Moisture levels were 1-2% higher in the surface surface soils during summer months, which is unlike the previous two years. This is a result of the abundant summer precipitation. The moisture levels of the surface soils

were 5-10% higher during the winter. This yearly fluctuation of soil moisture patterns was similar to results in 1981-1983, although the July values in 1984 were 4-5 times that of 1981, 1982 or 1983. Soil EC levels did not change significantly through the year while soil pH and organic carbon did show significant difference. The pH levels showed a sharp increase in the April sample in comparison to the other sampling periods. EC and organic carbon readings for 1984 were very similar to 1981-1983 data.

Soil bacteria fluctuated in an annual cycle characterized by a winter-spring high and a summer low. Bacterial counts throuth the year were much more evenly dispersed than in previous years, probably because of the abundant summer precipitation. The bacterial counts were $\pm$ 50% lower in subsurface soils (5-15 cm) than surface soils (0.5 cm). Fungal populations showed a peak in April of 40.3 m hyphae/g and a minimum in July of 12.8 m hyphae/g.

Respiration rates showed an annual cycle that corresponds to the bacteria counts with a winter high (6.6 meg $CO_2 \times 10^{-4}$/g/hr) and a summer low (4.0 meq $CO_2 \times 10^{-4}$/g/hr. Dehydrogenase activity exhibited no pattern in 1984. The high was in October at 8.4 mg formazan/liter and the low in July at 7.2 mg formazan/liter. This unlike data from 1981-1983 which showed more definite winter peaks.

Correlations between chemical microbiologic factors identified several major relationships:

(1) High bacterial counts, total fungi, algae, dehydrogenase, and microbioal respiration levels were associated with relatively moist soils.

(2) Bacterial numbers, fungi and their activities tend to be positively correlated with organic-matter.

The correlation coefficients are generally low (0.2-0 5) for most analyses, but the relationships do represent logical patterns and will serve as valuable baseline information.

3.2.7 Revegetation Success on Disturbed Sites

Disturbed areas along the main access road to the plant site were revegetated in the fall of 1982. Other areas near the retention dam along the water well access road and on two topsoil stockpiles were revegetated in the fall of 1983. Areas were reseeded in 1982 using both hydromulching and drill seeding, with transplants in certain locations. Areas revegetated in the fall of 1983 were drill seeded, mulched with a straw mulch and in many locations transplants were used to revegetate the barren slopes. In June of 1983, four revegetation monitoring sites were located between the Watson Road turnoff and the Security Station to evaluate the success of the 1982 revegetation efforts. The sites were samples in the spring and fall of 1983. Similar monitoring sites were located near the retention dam, along the water well access road and on the two topsoil stockpiles to monitor the success of the revegetation on the sites seeded in the fall of 1983. All 1983 and 1982 reseeded areas were sampled in the spring and fall of 1984 to evaluate the emergence/survival of both seedlings and transplants after the winter cold temperatures and after the critical summer period.

For the 1982 reseeded areas the average density of all plots on all sites decreased from 9.6 plants/m^2 in the fall of 1983 to 7.4 plants/m^2 in the fall of 1984. By the fall of 1984 of the 12 plots sampled six fell into the excellent category according to Vallentine (1974), one into the good category

and five in the poor category. The most commonly occurring species in the fall of 1984 was western wheatgrass (4.9 plants/m^2), followed by sagebrush (1.2 plants/m^2), and Indian ricegrass (0.3 plants/m^2).

A total of 17 revegetation monitoring sites located in areas reseeded in the fall of 1983 were sampled in the spring and fall of 1984. The average density of all plots on all sites increased from 18.2 plants/m^2 in June to 29.4 plants/m^2 in October. In the spring of 1984, three of the eight plots sampled would be considered excellent revegetation success, 2 in the good category, 1 fair, and 2 in the poor category. In the fall of 1984, nine of 17 plots fell into the excellent category, 4 into the fair and 4 into the poor. The most commonly occurring species in the spring was sagebrush (2.9 plants.m^2), fourwing saltbush (1.7 plants/m^2) and shadscale (1.4 plants/m^2). In the spring it was too early to be able to distinguish grass species. However by fall, the most commonly occurring species were western wheatgrass (9.6 plants/m^2) and Indian ricegrass (8.8 plants/m^2). Sagebrush decreased in total plant density to 1.8 plants/m^2, fourwing saltbush to 0.6 plants/m^2 and shadscale to 1.1 plants/m^2. There was an increase in cuneate saltbush from 0 plants/m^2 in the spring to 1.3 plants/m^2 in October.

3.3 PROGRAM DESCRIPTION

3.3.1 Objectives

The three main objectives of the vegetation program are:

- To document the existing vegetation conditions during and after various stages of development, including the range of variation exhibited temporally and geographically.
- To quantify plant responses to environmental impacts created by development, thereby allowing comparisons of plant responses in areas of little or no impact with those in areas of relatively high impact.
- To measure the success of revegetation techniques on the processed shale disposal area and other areas that may be disturbed during operations.

The first revegetation activities occurred in 1982 and continued into 1983. The initial disturbance was associated with construction of the new road to the plant site. Monitoring was initiated in 1983 on this area for plant establishment and revegetation success. The area of greatest impact to the vegetation in terms of area disturbed, however, will be the processed shale pile. Revegetation techniques for processed shale are still being investigated and are discussed in Chapter 7. Many of the parameters discussed below will be used in monitoring the processed shale area, however, it is anticipated that other parameters may be identified from the special revegetation studies that could be added to the vegetation monitoring program at a later date.

3.3.2 Site Locations

The vegetation resources program continued to use the areas of sampling established in the 1974-1976 baseline work and those areas initiated during 1981

by the addition of several new studies. The locations of all the study sites are shown in Figure 3.3-1. Details for the selection of the sites are discussed fully in the WRSP Environmental Monitoring Manual (1982).

3.3.3 Methods

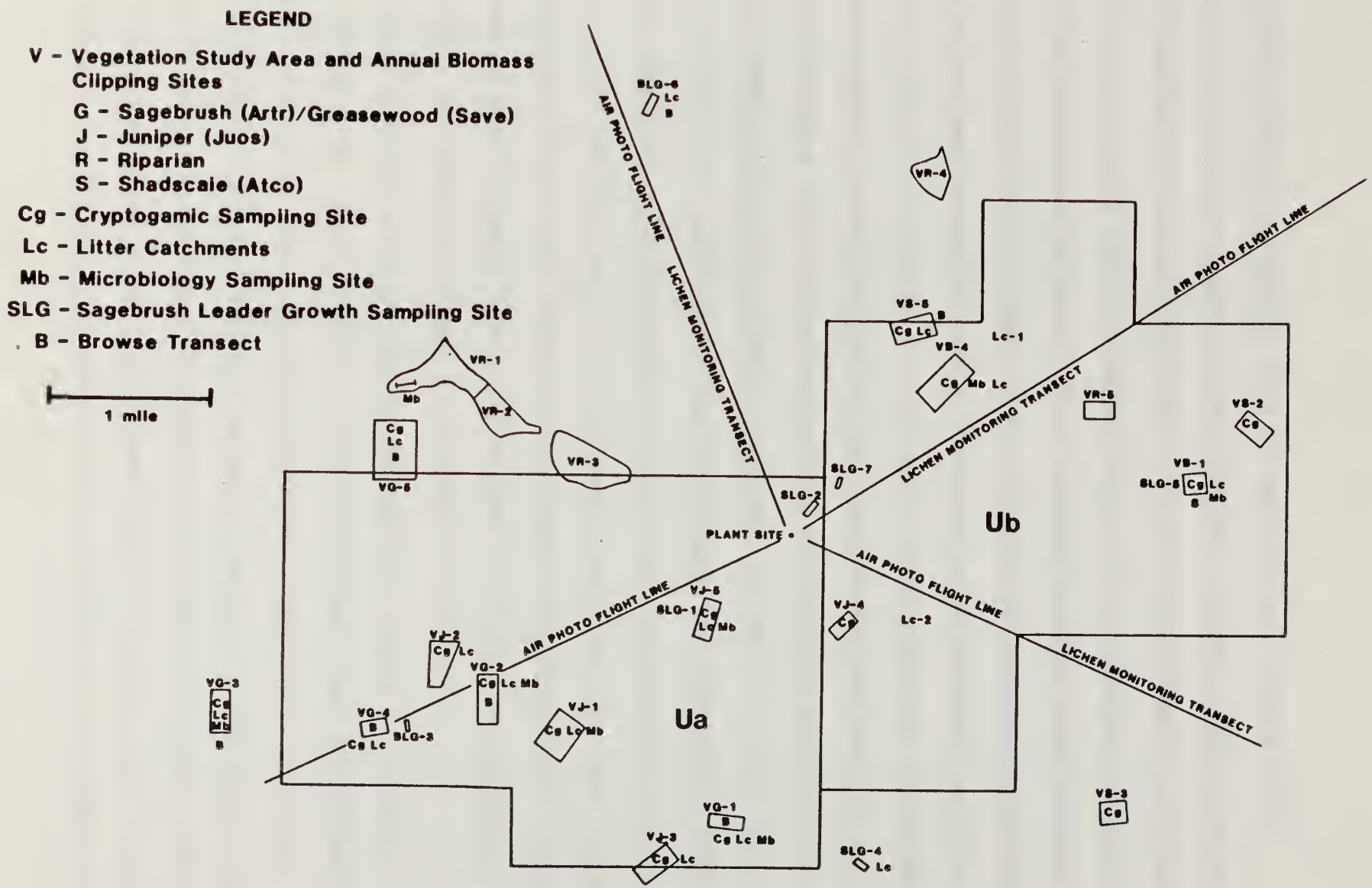
Reference to vascular plant species in tables is occasionally done by referring to the plant species by the commonly used four letter plant symbol as given in USDA Forest Service General Technical Report INT-83. The four letter symbols also correspond to the six letter symbols used in Table IV-1 of the Final Environmental Baseline Report for the White River Shale Project.

The methods used during the 1984 program are essentially the same as those utilized during the previous years of study. The WRSP Environmental Monitoring Manual (EMM) contains a detailed description of the methods employed and the schedule for sampling. Deviations from the EMM occur primarily when sample sizes are adjusted to provide for more statistically valid data or when field conditions necessitate a change. Any such changes are described in the appropriate section of this report.

3.3.4 QA/QC Program

The Quality Assurance and Quality Control program described in the EMM was initiated during the 1982 program and continued in 1983 and 1984. The field and laboratory data collection has been verified and thoroughly documented. All pertinent data, both raw and summarized, have been placed onto computer tapes under the direction of WRSOC and according to the format specified. Duplicate tapes were made for the Oil Shale Projects Office and for WRSOC files. Original data sheets are being kept in NPI files.

Figure 3.3-1. Location of Vegetation Resources Study Areas.



Soils analysis was the area for most concern in the QA/QC program. To assure quality, duplicate samples were analyzed on selected soils. Sample handling is important in the soil microbiology samples, since heat and time will create an incubation of the organisms (bacteria and fungi) and artificially increase their numbers. The samples are currently being cooled within a few minutes of being taken and kept in cold storage (walk-in refrigerator) until analysis. Analysis begins as soon as the soils are received in the lab also to reduce any incubation time.

Soil analysis methods are standardized, yet, there is often considerable variation when analyzing for particular elements. This suggests that the variability is in the soil matrix and care must be taken in deriving conclusions about differences in elements with high variability.

3.4 PROGRAM RESULTS AND ANALYSIS

Seven separate components are included in the vegetation monitoring program in the EMM. Three of these are identified as operational parameters; production of annual plant biomass, sagebrush stem growth, and soil chemistry. These will probably be continuously monitored. Three components are listed as potential parameters including, lichen growth, litterfall, and soil microbiology. Along with this there are portions of the soil chemistry and soil microbiology parameters that will be included as contingency parameters. The results of each of these components along with monitoring animal use of plants on tract and the revegetation success component, are reported in the following sections.

3.4.1 Production of Annual Plant Biomass

In June 1984, five productivity study areas were visited in each of the four major vegetation types identified during the baseline program (Refer to Figure 3.3-1 for the locations). In each study area, plant cover was recorded and above-ground annual plant biomass was harvested from twenty 0.25 m plots. Plants were clipped at ground level, and returned to the lab for weighing. Oven dried weights and cover percentages are reported in Table 3.4-1.

Previous analyses have shown that annual species biomass is related to spring precipitation. Precipitation records for the water year 1984 showed that the critical months for annual species biomass were below normal (refer to Chapter 6, Water Resources). Multiple regression analysis of the 1975-84 data for annual plant biomass and monthly precipitation shows that January, April, and May precipitation are significantly correlated ($\alpha \leq .01$) with annual biomass. Precipitation in the other months add little if any strength to the regression

Table 3.4-1 Biomass production of annual understory vegetation of four primary vegetation types during 1984 and compared with previous years.

Sample Location (1)	VEGETATION TYPE: Shadscale Production (g/m^2)	Shadscale Plant Cover (%)	Sagebrush-Greasewood Production (g/m^2)	Sagebrush-Greasewood Plant Cover (%)	Juniper Production (g/m^2)	Juniper Plant Cover (%)	Riparian Production (g/m^2)	Riparian Plant Cover (%)
1	29.8	15.0	11.0	5.1	0.0	0.1	70.1	23.9
2	22.5	11.3	5.2	2.3	0.5	0.3	116.0	37.6
3	14.8	8.2	39.8	21.7	1.2	0.5	89.1	21.5
4	4.8	2.0	3.4	1.8	0.8	0.2	(4)	(4)
5	15.6	12.3	2.5	1.1	0.2	0.1	20.4 6.9	2.0
1984 Avg.	17.5	10.0	12.4	6.4	0.5	0.2	70.5	21.3
1983 Avg.	61.5	10.2	79.2	11.3	1.2	0.4	116.4	14.9
1982 Avg.	24.7	6.4	21.4	5.5	0.4	0.2	68.1	18.2
1981 Avg.	9.2	3.4	15.8	4.8	0.6	0.2	51.5	17.4
1980 Avg.	21.8	2.3	8.9	0.9	0.5	trace	(3)	(3)
1979 Avg.	16.5		16.9		6.3		82.5	
1978 Avg.	5.4		35.1		1.6		80.0	
1977 Avg.	0.0(2)		0.0(2)		0.0(2)		20.6	
1976 Avg.	3.8		20.9		0.3		30.6	
1975 Avg.	224.3		51.1		3.8		590.0	

(1) Each value is a mean of 20 plots within areas sampled during and since the Baseline.
(2) Vegetation was not sampled (too meager to harvest).
(3) Biomass sampling data unavailable because of sample handling problems.
(4) Site destroyed by flooding.

(Figure 3.4-1).

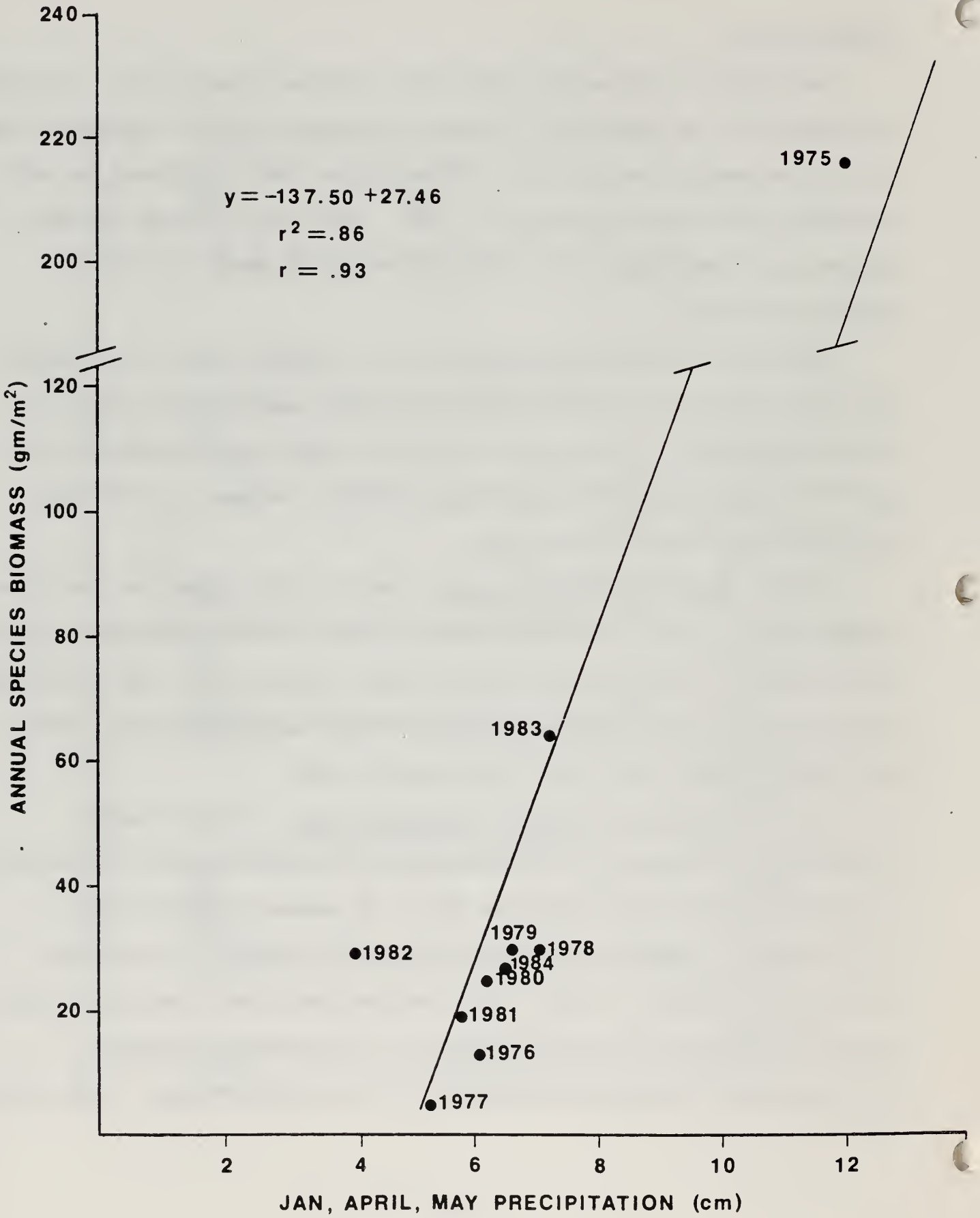
Comparisons of 1984 annual biomass data with the preceding years are shown in Table 3.4-1. In comparisons of biomass averages of all four vegetation types for the ten years of record, 1984 ranked among the lowest in biomass and was under 50% of the biomass production in 1983. This loss of herbage and seed resource may have played in part the rapid decline in rodent and rabbit populations in 1984.

The riparian vegetation type again had the largest values for production and cover of the four vegetation types considered, averaging 70.5 gm/m^2 and 21.3%, respectively. The juniper type had the lowest figures averaging 0.5 gm/m^2 for production and 0.2% for cover. Production values for individual vegetation types are discussed below.

3.4.1.1 Shadscale Vegetation Type. Annual species biomass was the fifth highest ($X = 17.5\ gm/m^2$) of the ten years of record for this vegetation type in 1984. Cheatgrass was again the dominant annual species on this vegetation type and it occurred most frequently in protected areas underneath shrubs. Cover estimates averaged 10.0% with a range from 2% to 16%.

3.4.1.2 Sagebrush - Greasewood Vegetation Type. Annual species production in the sagebrush - greasewood areas averaged 12.4 gm/m^2. This total is the third lowest biomass yield to date. The general pattern of plant distribution was similar to the shadscale type with most of the production occurring underneath the shrubs. Areas between shrubs had a very sparce cover. Besides cheatgrass, an annual *Cryptantha* spp. and pepperweed (*Lepidium perfoliatum*) were occasionally found within this vegetation type. Cover values

Figure 3.4-1. Regression analysis of precipitation (January, April, May) with Annual Species Biomass.



for the annual species were averaged at 6.4 with a range of 1.1 to 21.7%.

3.4.1.3 Juniper Vegetation Type. The production of annual species in this vegetation type was low as is typical with the juniper zone. Average production was only 0.5 gm/m^2 compared with 1.2 gm/m^2 in 1983. The dominant annual species in this type was cheatgrass with some lambs' quarters (*Chenopodium album*) and pepperweed. The total cover in the juniper sites sampled averaged 0.2% cover which is comparable to that for 1981 and 1982 data but only one half the 1983 value.

3.4.1.4 Riparian Vegetation Type. As in all previous years, the riparian vegetation type produced the most annual plant biomass. Again, the dominant species was cheatgrass, with fair abundance of yellow sweetcover (*Melilotus officinalis*), pepperweed, and fat hen saltbush (*Atriplex patula*). The grazing pressure on the riparian areas is more severe than on the other vegetation types and much of this disturbance leads to an increase in the preponderance of annuals. These annuals may in turn serve as a source of food for animals during a short period in the spring. The production of annuals for 1984 averaged 70.5 gm/m^2. Average cover values for the riparian vegetation sites ranged from 2.0% to 37.6% with an average cover of 21.3%. One site VR4 was flooded in 1984 and was left with 15-30 cm of silt over the previous soil surface. Due to this flooding no data was available from this site.

3.4.2 Sagebrush Leader Growth

The methodology used for sampling sagebrush (*Artemisia tridentata*) stem growth measurements during 1984 was consistent with that used previously. The annual growth of 20 stems on each of 20 separate plants in each of seven

sampling locations (2800 samples total) were measured. Locations of the sampling sites are shown in Figure 3.3-1. Each measurement was from the bud-scale scar of the previous year to the tip of the new growth. This marks the tenth year that this data has been collected on sites SLG-1 through SLG-6 and the fourth year of data for site SLG-7.

Growing conditions for sagebrush in 1984 were excellent for stem growth, and this is reflected in the stem lengths. The variability of stem length is highly correlated with variability in winter precipitation (Figure 3.4-2). The precipitation for the winter period for 1984 averaged 9.6 cm which was the third highest average recorded. Stem length was slightly above the value that would be predicted strictly by the regression equation but it was still well within the 90% prediction interval (Figure 3.4-3).

Average stem length ranged from 5.6 cm at site 5 on the east edge of tract Ub to 9.0 cm at site 2 which is near the plant site (Table 3.4-2). The standard deviations for all seven sites are quite uniform which illustrates that the variability of stem growth is low.

Over the ten years of study, average sagebrush stem growth ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979 (Table 3.4-2). The data for 1984 on sagebrush leader growth (7.6 cm) was the second highest value recorded during this time period. An analysis of variance (ANOVA) was performed on the data (sites 1-6) for the ten years of record. The results, shown in Table 3.4-3, point out that there were significant differences between years. The results of the LSD mean separation test are shown in Table 3.4-2. An ANOVA test comparing sites also showed significant differences. Site 3 had significantly longer stem

Figure 3.4-2. Graph of sagebrush stem growth and winter precipitation.

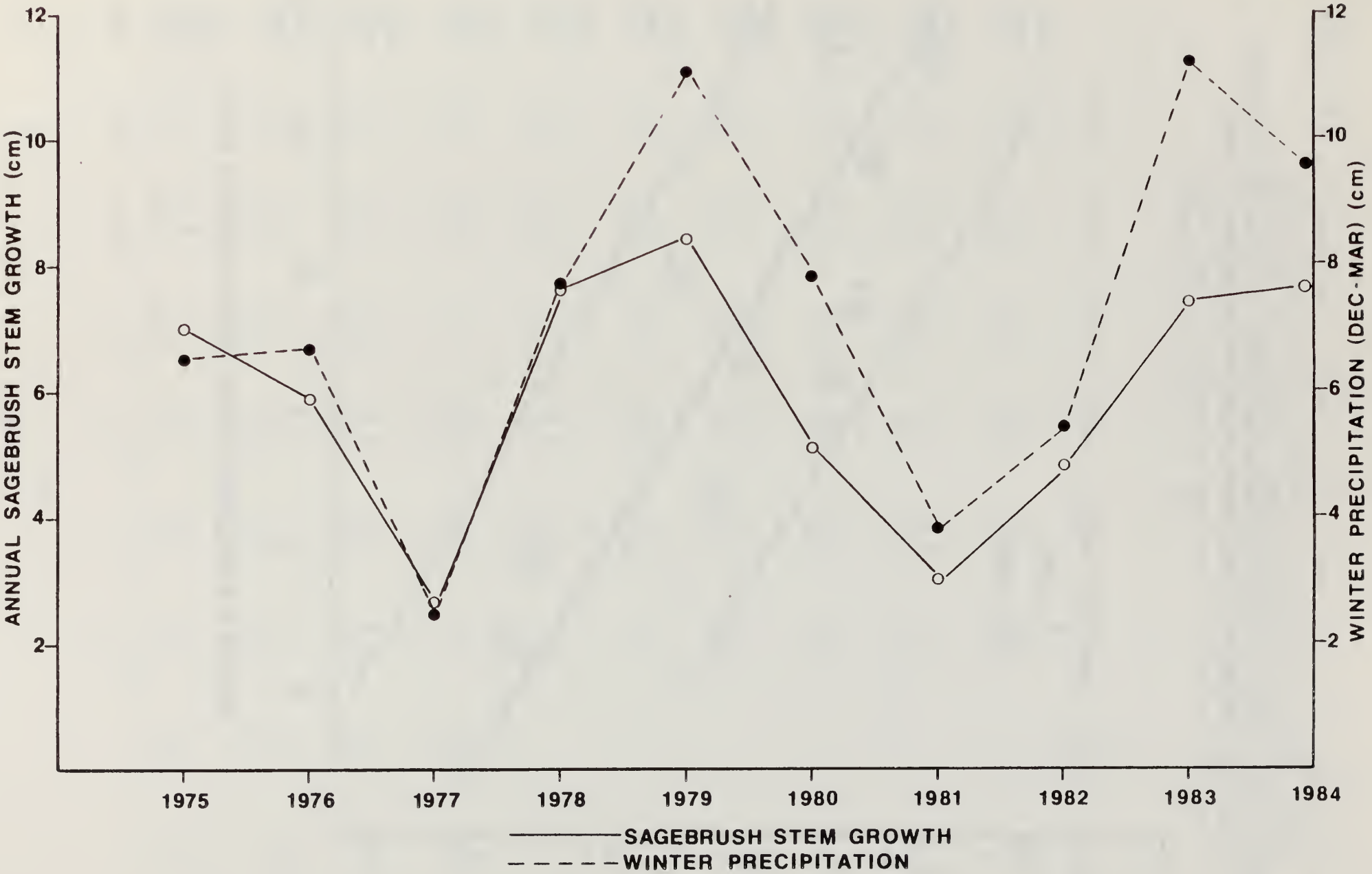


Figure 3.4-3. Regression of sagebrush stem growth and winter precipitation. The dashed line represents the 90% precipitation level.

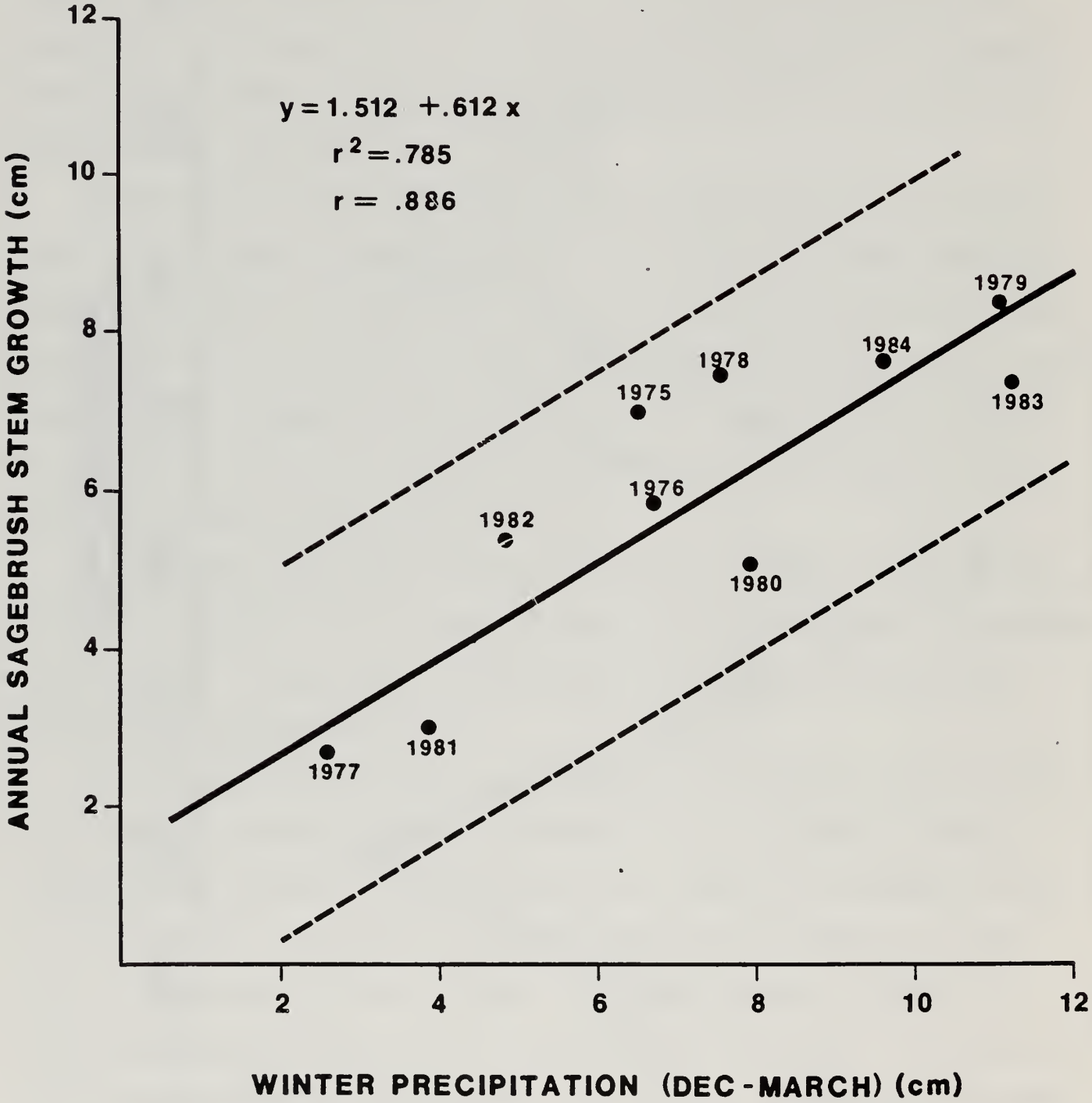


Table 3.4-2 A comparison of sagebrush stem growth over a nine year period, 1975 to 1984 on sites related to prototype oil shale tracts Ua and Ub. Each value is the mean length of 20 stems on 20 plants (i.e., 400 observations/site/year). Values are expressed in centimeters. Averages followed by a common letter are not significantly different as analyzed by ANOVA and LSD mean separation tests with $\alpha \leq .05$.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Average
1975								
Mean	7.4	6.9	9.7	5.6	7.1	5.4		7.0^{d}
SD	2.1	1.1	1.4	1.0	1.3	1.5		
1976								
Mean	6.2	6.2	7.0	5.5	5.4	4.8		5.9^{c}
SD	1.0	1.6	0.9	1.0	1.2	1.1		
1977								
Mean	2.1	2.0	4.0	2.2	2.8	2.8		2.7^{a}
SD	0.4	0.3	1.0	0.3	0.6	0.6		
1978								
Mean	8.4	8.1	10.1	6.4	5.6	6.5		7.5^{de}
SD	1.8	2.9	2.2	1.1	1.6	2.5		
1979								
Mean	7.6	9.9	9.9	8.2	7.3	7.7		8.4^{e}
SD	2.0	2.2	2.5	2.1	1.8	1.9		
1980								
Mean	4.6	6.4	7.5	4.8	3.9	3.6		5.1^{bc}
SD	1.4	1.9	1.7	1.3	1.1	1.0		
1981								
Mean	2.8	3.3	3.1	2.8	2.2	2.8	3.9	3.0^{a}
SD	0.8	0.7	0.6	0.5	0.5	0.5	0.8	
1982								
Mean	4.5	5.2	5.9	4.8	3.0	4.8	5.5	4.8^{b}
SD	1.2	1.4	1.1	1.1	0.6	1.5	1.2	
1983								
Mean	7.1	7.9	8.1	7.4	4.6	9.4	8.5	7.4^{de}
SD	1.8	3.0	1.8	2.4	0.8	2.3	2.7	
1984								
Mean	7.2	8.9	7.5	8.2	5.6	8.1	9.0	7.6^{de}
SD	2.0	2.0	1.2	1.6	1.9	2.1	2.3	
AVG	5.8^{bc}	6.5^{cd}	7.3^{d}	5.6^{ab}	4.8^{a}	5.6^{ab}		

Table 3.4-3 Two-Way Analysis of Variance test of sagebrush stem growth for 1975 through 1984.

	SS	df	M.S.	F-ratio
Years	224.45	9	24.94	30.60*
Sites	37.67	5	7.53	9.24*
Error	36.68	45	0.82	
Total	298.79	59		

*significant at $\alpha \leq .01$.

lengths than any of the other sites (except Site 2). Sagebrush leader growth appears to provide a realistic index of the year-to-year variability that occurs within the oil shale tracts and provides a good monitoring device to estimate plant variability within the ecosystem. However, the relationship does not take into account all the variability in the system. Thus, the 90% predictive level will be used to identify outlier values that may occur in future years.

In addition to the leader growth measurements for sagebrush, measurements for three other species, fourwing saltbush (Atriplex canescens), rabbitbrush (Chrysothamnus greenii), and greasewood (Sarcobatus vermiculatus) were sampled in 1984 as a comparison for sagebrush. Rabbitbrush and greasewood were sampled from Site 7 only while fourwing saltbush was sampled from LC-1 since sampling at Site 7 would involve clipping plants that were clipped in 1983 due to the low number of fourwing saltbush at that site.. One hundred samples were taken for each species. The results are reported in Table 3.4-4. Average leader growth was 42.5 cm $\pm$ 4.6 for fourwing saltbush, 22.5 cm $\pm$ 4.0 for rabbitbrush, and 40.7 cm $\pm$ 3.5 for greasewood. The averages for all three species are higher than the averages for sagebrush (2-4 times). Comparisons of the 1981-84 data showed that 1984 averages were higher for most species. Saltbush increased by 73%, sagebrush by 6%, greasewood by 125%, and rabbitbrush showed a slight decline (1%). Sagebrush which increased by 6% from 1983 to 1984 at Site 7 appears to represent accurately the fluctuations of other shrubs to environmental change, although the changes in growth of sagebrush may not be as dramatic. It appears that sagebrush is a suitable measure of general plant resources on oil shale tracts Ua and Ub.

Table 3.4-4 Average leader growth measurements (cm) of fourwing saltbush, greasewood, rabbitbrush, and sagebrush from Site 7, October 7 1983, and comparisons for 1981-1984.

	ATCA		SAVE		CHGR		ARTR	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
1981	14.0	6.3	3.3	1.9			3.9	0.8
1982	17.3	9.9	7.8	3.3	14.7	6.6	5.5	1.2
1983	24.5	3.8	18.1	2.4	22.7	3.3	8.5	2.7
1984	42.5	4.6	40.7	3.5	22.5	4.0	9.0	2.3

3.4.3 Litterfall Measurements

Litterfall is being measured under the canopy of the dominant shrubs and juniper trees on the tracts. Measurements of litterfall are important because excessive litterfall of leaves and twigs from shrubs and juniper may indicate undue stress of plants. Excess litterfall and reduced leaf retention has been observed in areas of high air pollution (Taylor, 1974; Miller, 1975; National Academy of Science, 1977; Miller and Elderman, 1977). Litterfall is also essential to the normal functioning of many soil parameters including nutrient cycling, and as a food source for many small animals. The area around shrubs where the litter accumulates is the nutritional "storehouse" for arid plant communities (Garcia-Moya and McKell, 1970; Bjerregaard, 1971) and any significant change in litterfall would result in changes in many ecosystem functions.

A total of 242 littertraps were sampled during 1984. Seven shrub species had 30-40 traps or replications placed beneath their canopies. The seven species sampled were sagebrush, fourwing saltbush, shadscale (*Atriplex confertifolia*), Green's rabbitbrush, hopsage (*Grayia spinosa*), Utah juniper, (*Juniperus osteosperma*), and greasewood. The litter traps were rectangular in shape with dimensions of 50 cm x 100 cm or 1/2 m^2. The sides of the traps were 16 cm in height to prevent litter from blowing out of the traps. The bottom of the traps consisted of a fine mesh window screen which is small enough to catch most of the litter fragments, but will allow water to pass through and prevent decomposition. The 1981 litter traps did not have a fine enough screen for the six shrubs, but they were suitable for juniper. Thus, the 1981 traps were

utilized exclusively under juniper in 1982-1984. The new 1/2 m^2 traps could be joined together to form a complete trap around a shrub. A size index for each plant was also calculated so adjustments or comparisons could be made for litterfall amounts from small or large plants. The size index is computed by multiplying the height by the crown diameters (two directions) to obtain a volume measure. If the crown diameter was over 1m then only 1 meter was used in the calculation of the size index since litter would otherwise fall outside of the trap. This approximates a volume figure which can then be used to compare different sized individuals within a species, as well as between species.

The litter traps were visited in June and October and the litter for the corresponding period (i.e., June-October) was removed, placed in bags and the traps replaced. The litter samples were taken to the lab, oven dried for 14 days at 25°C, separated into components, i.e. leaf, stem, seed, inflorescence and mixtures of each and weighed. The average composition and weight for each species is summarized in Table 3.4-5.

Table 3.4-6 shows the average litterfall for each species for the sampling periods. Litterfall measurement compares favorably to other values reported in the literature (West, 1979; Gottfried and Ffolliott, 1983). Figure 3.4-4 shows the seasonality of the litterfall. Most species studied showed highest amounts during the summer when leaves are being dropped to reduce water stress. This is different from most forest ecosystems where late fall receives the greatest amounts (Gottfried and Ffolliott, 1983). Utah juniper had the greatest litterfall for the 12-month period (October 1983-October 1984). However, the plants were also the largest. On a per cubic unit basis, shadscale produced the

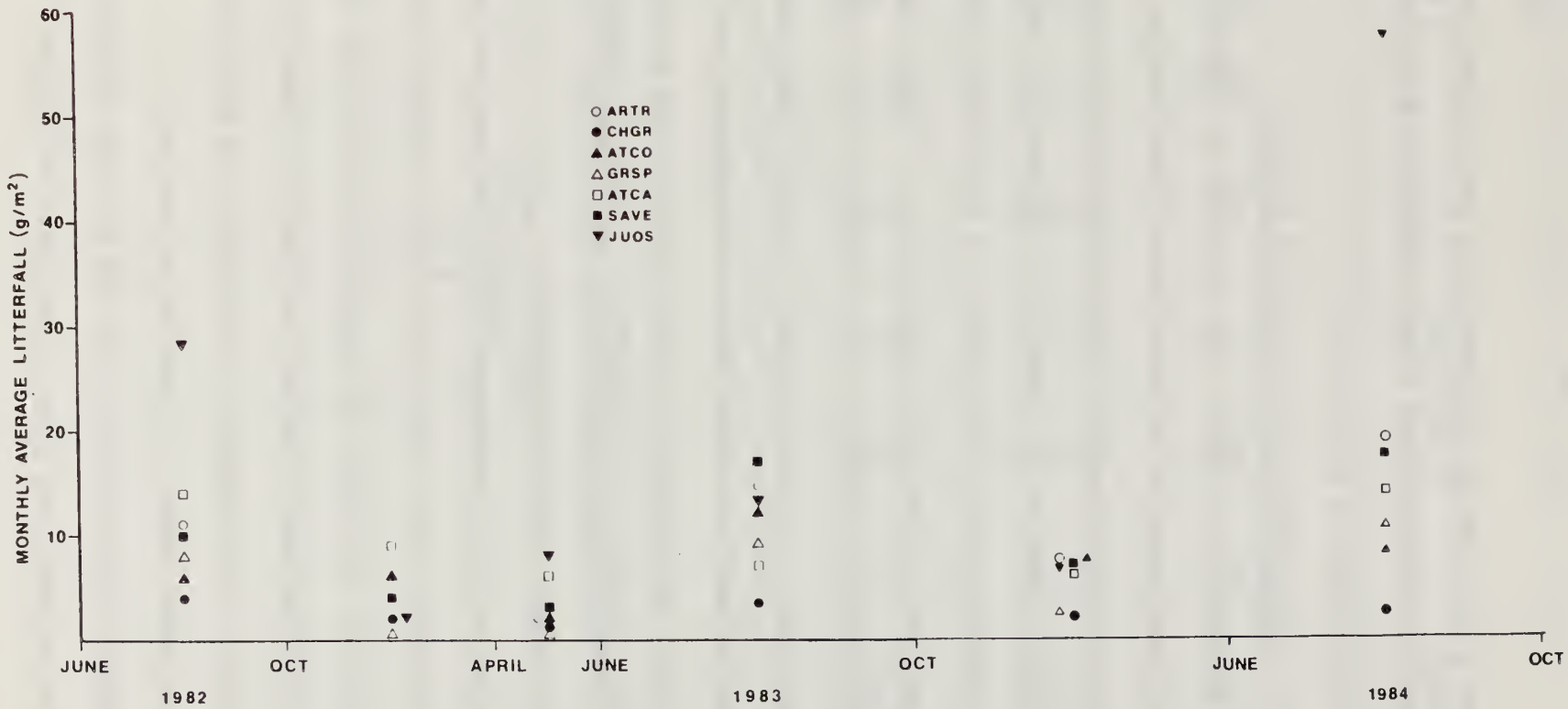
Table 3.4-5 Litterfall composition, total litterfall, size indexes, and total litter per size index for each of the seven species studied for the period October 1983-October 1984.

Species	% Leaf	% Stem	% Seed	Inflor.	Mixtures	Total/m	SI	Litter (g) Size Index/Yr
ARTR	66	23	0	11	0	137.0	.37	370.27
SAVE	58	32	0	0	10	126.07	.65	193.95
GRSP	76	23	1	0	0	62.64	.39	160.62
CHGR	33	52	0	14	1	26.03	.33	78.88
ATCO	57	31	10	2	0	94.97	.15	633.13
ATCA	65	4	11	0	0	102.89	.72	142.90
JUOS	86	7	7	0	0	278.39	2.70	103.11

Table 3.4-6 Litterfall on the seven species studied. Values represent a monthly average for the period sampled. Values are expressed as grams of oven-dried biomass/meter^2.

	SPECIES						
Sample Period	ARTR	SAVE	GRSP	CHGR	ATCO	ATCA	JUOS
June-October (82)	45.04	41.39	32.00	14.87	26.36	54.35	112.44
June-October (83)	58.60	70.86	34.70	13.60	48.90	27.90	53.90
June-October (84)	75.88	70.09	42.30	9.52	33.42	55.13	225.70
October (82)-June (83)	14.63	29.33	3.83	14.60	44.92	80.53	44.46
October (83)-June (84)	61.12	55.98	20.34	16.51	61.55	47.76	52.69
12 Month Total							
June (82)-June (83)	59.67	70.72	35.83	29.47	71.28	134.88	156.90
June (83)-June (84)	119.72	126.84	55.04	30.11	110.45	75.66	106.59

Figure 3.4-4. Seasonal distributions of litterfall over the 16 months of sampling. Values represent monthly averages for the period between collection.



most litter, followed by sagebrush with yield equivalents of 633.13 $g/m^3/yr$ and 370.27 $g/m^3/yr$, respectively (Table 3.4-5). A comparison of results for 1982-1984 are shown in Figure 3.4-4.

3.4.4 Assessment of Animal Use of Plants

The monitoring of animal use of plants is important during the construction and operational phase of the White River Shale Project. Impacts of the operation on browsing animals may be reflected through their use of browse shrub species (i.e., heavier or lighter utilization than the average usage).

To assess the use on the tracts, a Cole Browse Survey was run in April of 1984 at six sites using three key species. Overall animal use of key shrub species in 1984 was moderate (39% leader use). This value was less than 1982 (51% leader use), but much greater than 1983 (18% leader use). Shrub usage was attributed primarily to sheep which were observed grazing at the time of sampling near the transects in the shadscale and greasewood vegetation types. Signs of rabbit damage on greasewood were common while signs of deer browsing were less common along the transects.

Results of the Cole Browse Survey are given in Table 3.4-7. Greasewood received heavier leader usage (71%) than sagebrush (42%) or shadscale (6%). Form class, an indication of browsing received from the previous two years, showed that greasewood received the heaviest usage with 70% of the plants being in the heavily used category. Form class and age class together indicate the allowable browse usage of a particular species.

Shadscale and greasewood had 28% and 14%, respectively, of the plants within the decadent age class, down from 1983 values, they also had 8% and 4% in

Table 3.4-7 Results of Cole Browse Survey taken in April 1984.

Species Sampling Site	Form Class % None	Lt.-Mod.	Heavy	Dead	Seedling	Age Class % Young	Mature	Decad.	% Leader Use	Leader Length
ATCO										
VS1	0	92	8	0	0	0	84	16	0	29.8
VS5	0	44	36	20	16	0	44	40	11.4	16.9
$\bar{x}$	0	68	22	10	8	0	64	28	5.7	23.0
ARTR										
VG2	0	40	56	4	4	0	88	8	60.2	24.3
VG1	0	84	16	0	0	4	92	4	23.8	46.6
$\bar{x}$	0	62	36	2	2	2	90	6	42.0	
SAVE										
VG4	0	36	64	0	0	0	84	16	57.6	0.0
VG3	0	16	76	8	8	0	80	12	83.9	0.4
$\bar{x}$	0	26	70	4	4	0	82	14	70.7	0.2

Table 3.4-8 Leader lengths of caged and non-caged big sagebrush shrubs. Caged shrubs were significantly longer as tested by ANOVA ($F = 20.2$; $\alpha \leq .01$).

	Leader length (mm) Caged	Leader length (mm) Non-Caged
VG1	60.9	37.9
SLG6	110.9	95.9

the seedling category unlike 1983 when there were no seedlings observed. This trend is probably characteristic of an arid or semi-arid environment where seedling establishment occurs commonly only in favorable years (once in ten to twenty years).

Caged plots were established in October 1982 at SLG6 on the north side of the White River and VG1 at the head on Southam Canyon. The length of 20 leaders from each caged shrub (plot) and an adjacent non-caged shrub were measured in April, 1984. Results of the data were tested statistically and showed that there was a significant difference in leader length between the caged and non-caged shrubs at site VG1 (Table 3.4-8). At both sites, the caged plants had longer average leader lengths than the uncaged plants (VG1-161%; SLG6-116%). This difference between caged and non-caged shrubs indicate that browsing was severe at VG1 but only moderate at SLG6.

3.4.5 Use of Lichens as Biological Monitors of Air Pollution

The purpose of the lichen monitoring program is to document the existing conditions of the saxicolous lichen community within the proposed development area of the White River Shale Project, and to develop procedures/methodologies that adequately measure existing conditions of the lichen communities. These data would be used to detect changes in those communities that may be attributable to oil shale development activities.

Characterization of 18 saxicolous lichen communities along three transects radiating out from the proposed plant site was initiated in 1982 and has continued through 1984. The parameters measured at each site were selected from several parameters evaluated during 1982 and 1983 studies. They include: total

cover (an ocular estimate of the cover attributable to both lichens and mosses), the number of species per quadrat, and the frequency of each saxicolous lichen. In addition to the ecological parameters measured, a permanently marked photo-plot has been photographed each year at each of the 21 stands. These permanent photo plots will serve as a visual means of detecting changes in the lichen community.

Emphasis of the 1984 lichen monitoring program has been on the characterization of the lichen communities using key parameters and the replicability of those parameters from year to year. Characterization of the lichen communities included: the frequency of all species (only frequency values of the most prevalent species used to compare year to year variation); number of the most prevalent species (average number of species encountered per quadrat); and percentage of total lichen cover. These three parameters: percent cover, number of species/quadrat and most prevalent species have been used to characterize the lichen communities at each stand and will be used after mining operations start to monitor the condition of the saxicolous lichen community. Results for the 1984 lichen monitoring program is presented in Table 3.4-9 by transect (NW, NE, SE) and by stand.

There was a large variability between stands along the NW transect. Total cover values ranged from 19% at NW3 to 29% at NW4 and NW7. Stands NW1 and NW2 were similar to NW3 with 21% and 22%, respectively. NW5 was 27% and NW6 was intermediate at 25%.

The number of species/quadrat was not as variable. Stands NW1 and NW3 had six species/quadrat, NW2 five species/quadrat, and the remaining stands each

with seven species/quadrat. Lecanora peltata was among the most prevalent species at stands NW3, 4, 5, 6, and 7. Prevalent lichen species at stands NW1 and NW2 were at the crustose life form.

Total lichen cover for all NE stands, except NE5, was approximately 30%. The NE5 stand was 54%, the highest encountered at any of the 18 stands sampled.

The number of species/quadrat was also slightly higher at NE5 (9) than at the other stands (8). The most prevalent species list included exclusively crustose lichens except at NE3 and NE5 were Lecanora peltata a foliose species was, respectively, the 8th and 9th most prevalent species. A summary of the field sampling is shown in Table 3.4-9.

The amount of total lichen cover and number of species/quadrat was high along the SE transect in relation to values for the other two transects. Although a low of 24% was encountered at stand SE3, stands NW4, 5, and 6 was approximately 38%, stand SE2 32%, and a high at 53% of SE1. There were approximately 8 species/quadrat at each SE transect stand except SE6 where 9 species/quadrat were encountered. L. peltata was among the prevalent species at stands SE3 and SE5, the prevalent species at all other stands were crustose species.

A summary of the stand field studies conducted from 1982-1984 are presented for each stand in tables 3.4-10, 11, 12. The number of lichen species/quadrat encountered in 1984 varied only slightly from previous estimates. For the NE transect 1984 estimates were not significantly different from 1982 and 1983. The number of species/quadrat estimated at stand 2 of the NW transect was slightly lower than 1983 estimates, however, it was the same as 1982. The number

Table 3.4-9 Frequency for most prevalent species, total lichen cover, and number of lichen species/quadrat for stands along NW, NE, and SE transects, 1984.

	NW Transect Stand No.							NE Transect Stand No.				
Species	1	2	3	4	5	6	7	1	2	3	4	5
Acarospora strigata	100	100	95	90	90	100	80	90	100	100	100	95
Acarospora smaragdula	40	60	35	35	80	50	45	15	55	10	65	30
Caloplaca trachyphylla	55	10	20	40	45	20	25	65	80	75	75	100
Candelariella rosulans	80	85	65	80	40	90	80	80	90	85	70	95
Lecanora caesiocinerea	30	35	60	70	55	65	85	80	85	70	90	65
Lecanora muralis	25	5	10	20	40	25	35	10	0	20	15	35
Lecanora mutabilis	20	45	70	65	50	50	85	45	80	80	85	80
Lecanora peltata	20	25	20	45	15	40	55					
Lecidia auriculata								50	5	20	5	50
Lecidia stigmatea	65	40	50	50	35	65	45	70	55	85	75	55
Rhizocarpon disporum												
Staurothele rufa	100	100	100	100	90	100	95	90	100	100	100	90
No. Species/ Quad	6	5	6	7	7	7	7	8	8	8	8	9
Percent Cover	21	22	19	29	27	25	29	30	31	32	29	54

Table 3.4-9 Continued

Species	SE Transect Stand No. 1	2	3	4	5	6
Acarospora strigata	80	100	100	100	90	100
Acarospora smaragdula	80	45	65	15	35	45
Caloplaca trachyphylla	90	70	40	90	100	100
Candelariella rosulans	50	85	90	90	100	100
Lecanora caesiocinerea	95	80	75	75	70	75
Lecanora muralis						
Lecanora mutabilis	55	50	60	50	75	55
Lecanora peltata	25	15	40	25	30	20
Lecidia auriculata	10	35	25	25	25	70
Lecidia stigmatea	55	70	50	60	95	55
Rhizocarpon disporum	65	0	0	0	0	0
Staurothele rufa	80	100	100	90	65	65
No. Species/ Quad	9	7	7	8	9	9
Percent Cover	53	32	24	38	37	38

Table 3.4-10 Total lichen cover, number of species/quadrant and frequency of the most prevalent species for each lichen monitoring stand along the NW transect. A summary of 1982, 1983 and 1984 data. Standard deviation in parenthesis. Mean separation for total cover and no. species/quadrant were by Fisher's Mean Separation Test.

Stand 1						Stand 2					
Species	82	83	84	Avg.	S.D.	Species	82	83	84	Avg.	S.D.
Staurothele rufa	100	95	100	98.3	2.89	Staurothele rufa	100	100	100	100.0	.00
Acarospora strigata	85	100	100	95.0	8.66	Acarospora strigata	85	90	100	91.7	7.64
Candelariella rosulans	95	75	80	83.3	10.41	Candelariella rosulans	95	80	85	86.7	7.64
Caloplaca trachyphylla	50	50	55	51.7	2.89	Lecidia stigmatea	45	60	40	48.3	10.41
Lecidia stigmatea	45	40	65	50.0	13.23	Lecanora caesiocinerea	50	60	35	48.3	12.58
Lecanora caesiocinerea	50	50	30	43.3	11.55	Acarospora smaragdula	40	40	60	46.7	11.55
						Lecanora mutabilis	45	35	45	41.7	5.77
No. Species/Quad	6	6	6	6.0	0.48	No. Species/Quad	!6	7	5	6.0	0.55 !
% Cover	19	20	21	19.6	0.85	% Cover	!20	22	22	21.2	1.50 !

Stand 3						Stand 4					
Species	82	83	84	Avg.	S.D.	Species	82	83	84	Avg.	S.D.
Acarospora strigata	70	90	95	85.0	13.23	Acarospora strigata	60	85	90	78.3	16.07
Lecanora mutabilis	80	65	70	71.7	7.64	Candelariella rosluns	60	75	80	71.7	10.41
Candelariella rosulans	70	65	65	70.0	5.00	Lecanora mutabilis	75	60	65	66.7	7.64
Staurothele rufa	60	50	100	70.0	26.46	Lecanora caesiocinerea	65	60	70	65.0	5.00
Lecidia stigmatea	70	75	50	65.0	13.23	Staurothele rufa	30	60	100	63.3	35.12
Acarospora smaragdula	45	45	35	41.7	5.77	Lecanora peltata	55	40	45	46.7	7.64
Lecanora caesiocinerea	0	40	60	33.3	30.55	Caloplaca trachyphylla	55	45	40	46.7	7.64
						Lecidia stigmatea	14	65	50	43.3	25.66
						Acarospora smaragdula	30	45	35	36.7	7.64
No. Species/Quad	6	7	6	6.2	0.59	No. Species/Quad	!7	7	7	7.3	0.15
% Cover	13	15	19	15.5	3.01	% Cover	!23	21	29	24.6	4.17

Table 3.4-10 Continued

Species	Stand 5 82	83	84	Avg.	S.D.
Acarospora strigata	85	75	90	83.3	7.64
Staurothele rufa	90	70	90	83.3	11.55
Acarospora smaragdula	70	60	80	70.0	10.00
Lecanora caesiocinerea	60	55	85	56.7	2.89
Caloplaca trachyphylla	50	35	45	43.3	7.64
Lecanora muralis	40	50	40	43.3	5.77
Lecanora mutabilis	35	30	50	38.3	10.41
Candelariella rosulans	35	35	40	36.7	2.89
No. Species/Quad	9	6	7	7.6	1.26
% Cover	26	23	27	25.3	2.33

Species	Stand 6 82	83	84	Avg.	S.D.
Acarospora strigata	85	70	100	85.0	15.00
Staurothele rufa	60	85	100	81.7	20.21
Candelariella rosulans	70	75	90	78.3	10.41
Lecanora caesiocinerea	80	70	65	71.7	7.64
Lecidia stigmatea	45	65	65	58.3	11.55
Acarospora smaragdula	50	55	50	51.7	2.89
Lecanora mutabilis	50	50	50	50.0	.00
Lecanora peltata	55	45	40	46.7	7.64
No. Species/Quad	7	7	7	7.0	0.35 !
% Cover	22	26	25	24.1	2.28 !

Species	Stand 7 82	83	84	Avg.	S.D.
Lecanora mutabilis	85	95	85	88.3	5.77
Staurothele rufa	85	85	95	88.3	5.77
Acarospora strigata	95	80	80	85.0	8.66
Lecanora caesiocinerea	75	70	85	76.7	7.64
Candelariella rosulans	50	65	80	65.0	15.00
Lecanora peltata	70	65	55	63.3	7.64
Lecidia stigmatea	25	65	45	45.0	20.00
Lecanora muralis	45	50	35	43.3	7.64
No. Species/Quad	6	7	7	6.8	0.47
% Cover	25	27	29	27.0	2.04

Table 3.4-11 Total lichen cover, number of species/quadrant and frequency of the most prevalent species for each lichen monitoring stand along the NE transect. A summary of 1982, 1983 and 1984 data. Standard deviation in paranthesis. Mean separation for total cover and no. species/quadrant were by Fisher's Mean Separation Test.

Species	Stand 1 82	83	84	Avg.	S.D.	Species	Stand 2 82	83	84	Avg.	S.D.
Acarospora strigata	80	80	90	83.3	5.77	Staurothele rufa	85	95	100	93.3	7.64
Staurothele rufa	75	70	90	78.3	10.41	Candelariella rosulans	95	90	90	91.7	2.89
Candelariella rosulans	85	65	80	76.7	10.41	Acarospora strigata	85	70	100	85.0	15.00
Caloplaca trachyphylla	70	70	65	68.3	2.89	Caloplaca trachyphylla	80	85	80	81.7	2.89
Lecidia stigmatea	50	55	70	58.3	10.41	Lecanora caesiocinerea	70	75	85	76.7	7.64
Lecanora caesiocinerea	35	55	80	56.7	22.55	Lecanora mutabilis	70	80	80	76.7	5.77
Lecidia auriculata	45	40	50	45.0	6.71	Lecidia stigmatea	35	75	55	55.0	20.00
Lecanora mutabilis	40	40	45	41.7	2.89	Acarospora smaragdula	35	0	55	30.0	27.84
No. Species/Quad	8	7	8	7.7	.95	No. Species/Quad	8	8	8	7.8	.29
% Cover	31	30	30	30.5	.82	% Cover	35	40	31	35.2	4.61

Species	Stand 3 82	83	84	Avg.	S.D.	Species	Stand 4 82	83	84	Avg.	S.D.
Acarospora strigata	90	90	100	93.3	5.77	Acraspora strigata	95	90	100	95.0	5.00
Staurothele rufa	95	70	100	88.3	16.07	Staurothele rufa	90	90	100	93.3	5.77
Candelariella rosulans	90	90	85	88.3	2.89	Lecanora caesiocinerea	70	90	90	83.3	11.55
Lecanora mutabilis	75	75	80	76.7	2.89	Lecanora mutubilis	70	70	85	75.0	8.66
Lecanora caesiocinerea	80	70	70	73.7	5.77	Caloplaca trachyphylla	75	75	75	75.9	.00
Lecidia stigmatea	35	90	85	70.0	30.41	Candelariella rosulans	70	65	70	68.3	2.89
Caloplaca trachyphylla	55	65	75	65.0	10.00	Lecidia stigmatea	50	70	75	65.0	13.23
Lecanora peltata	45	60	55	53.3	7.64	Acarospora smaragdula	50	45	65	53.3	10.41
No. Species/Quad	8	8	8	7.8	.31	No. Species/Quad	8	7	8	7.9	.42
% Cover	29	26	32	28.7	3.20	% Cover	25	27	29	26.7	2.26

Table 3.4-11 Continued

Species	Stand 5 82	83	84	Avg.	S.D.
Candelariella rosulans	95	95	95	95.0	.00
Caloplaca trachyphylla	90	85	100	91.7	7.64
Staurothele rufa	80	55	90	75.0	18.03
Lecanora mutabilis	80	65	80	75.0	8.66
Lecidia stigmatea	65	85	55	68.3	15.28
Lecanora caesiocinerea	80	50	65	65.0	15.00
Acarospora strigata	65	30	95	63.3	32.53
Lecanora peltata	65	65	60	63.3	2.99
Lecidia auriculata	55	50	50	51.7	2.89
No. Species/Quad	10	8	9	9.0	.82
% Cover	48	37	54	46.2	8.74

Table 3.4-12 Total lichen cover, number of species/quadrant and frequency of the most prevalent species for each lichen monitoring stand along the SE transect. A summary of 1982, 1983 and 1984 data. Standard deviation in paranthesis. Mean separation for total cover and no. of species/quadrant were by Fisher's Mean Separation Test.

Stand 1						Stand 2					
Species	82	83	84	Avg.	S.D.	Species	82	83	84	Avg.	S.D.
Acarospora strigata	50	55	80	61.7	16.07	Acrospora strigata	100	90	100	96.7	5.77
Acarospora smaragdula	60	60	80	66.7	11.55	Candelariella rosulans	90	85	85	86.7	2.89
Caloplaca trachyphylla	50	65	90	68.3	20.21	Caloplaca trachyphylla	75	70	70	71.7	2.89
Candelariella rosulans	45	45	50	46.7	2.89	Staurothele rufa	10	85	100	65.0	48.22
Lecanora caesiocinerea	95	95	95	95.0	0.00	Lecanora caesiocinerea	45	60	80	61.7	17.56
Lecanora mutabilis	70	5	55	43.3	34.03	Lecidia stigmatea	55	35	70	53.3	17.56
Lecidia stigmatea	15	35	55	35.0	20.00	Lecanora mutabilis	35	65	50	50.0	15.00
Rhizocarpon disporum	25	55	65	48.3	20.82						
Staurothele rufa	30	85	80	65.0	30.41						
No. Species/Quad	8	9	9	8.7	0.87	No. Species/Quad	7	6	7	6.7	0.49
% Cover	32	50	53	45.1	11.16	% Cover	30	25	32	29.2	3.59

Stand 3						Stand 4					
Species	82	83	84	Avg.	S.D.	Species	82	83	84	Avg.	S.D.
Staurothele rufa	85	100	100	95.0	8.66	Candelariella rosulans	90	90	90	90.0	0.00
Acarospora strigata	90	95	100	91.7	7.64	Caloplaca trachyphylla	80	80	90	83.3	5.77
Candelariella rosulans	90	90	90	90.0	0.00	Staurothele rufa	90	70	90	83.3	11.55
Lecanora caesiocinerea	100	85	75	86.7	12.58	Acarospora strigata	65	80	100	81.7	17.56
Lecanora mutabilis	60	50	70	56.7	5.77	Lecanora caesiocinerea	85	70	75	76.7	7.64
Lecidia stigmatea	45	50	50	48.3	2.89	Lecidia stigmatea	20	45	60	41.7	20.21
Lecanora peltata	50	45	40	45.0	5.00	Lecidia auriculata	30	40	25	31.7	7.64
						Lecanora peltata	35	20	25	26.7	7.64
No. Species/Quad	7	6	7	6.7	0.62	No. Species/Quad	8	8	8	7.8	0.31
% Cover	25	26	24	24.9	1.15	% Cover	26	31	38	31.9	6.04

Table 3.4-12 Continued

Species	Stand 5 82	83	84	Avg.	S.D.	Species	Stand 6 82	83	84	Avg.	S.D.
Caloplaca trachyphylla	95	95	100	96.7	2.89	Candelariella rosulans	90	95	100	95.0	5.00
Candelariella rosulans	95	95	100	96.7	2.89	Caloplaca trachyphylla	85	95	100	93.3	7.64
Lecanora mutabilis	95	80	75	83.3	10.41	Acarospora strigata	85	65	100	83.3	17.56
Lecidia stigmatea	70	85	95	83.3	12.58	Lecanora caesiocinerea	75	80	75	76.7	2.89
Lecanora caesiocinerea	85	90	70	81.7	10.41	Lecidia auriculata	55	70	70	65.0	8.66
Acarospora strigata	70	60	90	73.3	15.28	Lecidia stigmatea	50	75	55	60.0	13.23
Acarospora smaragdula	75	60	35	56.7	20.21	Lecanora mutabilis	45	50	55	50.0	5.00
Staurothele rufa	35	20	65	40.0	22.91	Acarospora smargdula	35	40	45	40.0	5.00
Lecidia auriculata	40	30	25	31.7	7.64						
No. Species/Quad	9	8	9	8.6	0.99	No. Species/Quad	7	7	9	7.6	0.78
% Cover	42	35	37	38.1	3.83	% Cover	30	34	38	33.9	3.88

of species/quadrat at stand NW5 was the same as 1983 estimates, both of which were lower than the 1982 figures.

With respect to the SE transect the number of species/quadrat estimated in 1984 varied from previous years at 3 stands: SE1, SE5, and SE6. At the SE1 stand, 1984 estimates were the same as 1983, both of which were higher than 1982 estimates. At the SE5 stand, 1984 estimates were the same as 1982 and both were slightly higher than 1983. The 1984 estimates at the SE6 stand was slightly higher than both 1982 and 1983 estimates.

Percentage total lichen cover at three stands, NE2, NE5, and SE1 were found to be significantly different from previous years' estimates. At NE2 the 1984 cover estimate was lower than 1983's but the same as 82. At NE5 1984's was higher then 1983 but the same as 1982. At SE1 1984's cover estimate and 1983's were both significantly lower than 1982.

The most frequently occurring species at each stand are listed in Tables 3.4.-10 to 3.4-13. This list represents a refinement of previous years species list which included all species encountered. As mentioned previously (1983 Report) the utility of less frequently occurring species in a monitoring system such as this one is minimal.

A summary of the 3 parameters measured over the last three years is presented in Table 3.4.6-13. Total lichen cover estimates for 1984 are higher than 1982 and 1983 estimates but is only significantly different from 1982's ($\alpha \leq .05$). The estimates for the number of species/quadrat for the 3 year-period were not significant different. Frequency values for 4 of the 12 most prevalent species were found to vary significantly from year to year ($\alpha \leq .01$). Acarospora

Table 3.4-13 Cover, number of species/quadrant and frequency of most prevalent species for years 1982-1984. Fisher Mean Separation Test.

Parameter	1982	1983	1984	F-Value
% Cover	27.8^{a}	28.6^{ab}	31.7^{b}	4.4*
Species/Quad	7.5^{a}	7.2^{a}	7.5^{a}	1.4^{ns}
% Frequency:				4.9**
Acarospora striqata	80.6^{a}	76.9^{a}	95^{b}	
Candelaria rosulans	76.9^{a}	76.9^{a}	80.8^{a}	
Staurothele rufa	67.8^{a}	72.5^{a}	92.5^{a}	
Lecanora caesiocinerea	13.9^{a}	16.7^{a}	13.3^{a}	
Lecanora mutabilis	40^{a}	32.8^{ab}	31.1^{b}	
Caloplaca trachyphylla	56.7^{a}	56.4^{a}	80.8^{a}	
Lecidia stigmatea	41.9^{a}	60.3^{b}	59.8^{b}	
Acarospora smaragdula	40.3	36.9^{a}	44.7^{a}	
Lecanora peltata	40^{a}	32.8^{ab}	31.1^{b}	
Lecidia auriculata	20.8	21.9^{a}	17.8	
Lecanora muralis	13.9^{a}	16.7^{a}	13.3^{a}	
Rhizocarpon disporum	1.4^{a}	3.1^{a}	3.6^{a}	

* - $\alpha \leq .05$

** - $\alpha \leq .01$

ns - Differences not significant

strigata and Staurothele rufa frequency values were significantly higher in 1984 than in the previous two years. This may be explained in part by the abnormally moist conditions occurring during the sampling period in 1984. Although sampling was done in August as in previous years, rather rainy and overcast conditions prevailed in 1984. Such conditions accentuate crustose lichen species such as A. strigata and S. rufa which in previous years may have been overlooked because they blended in with the rock surface due to there similarity in appearance to the "desert varnish" prevalent at many lichen monitoring stands. The inconsistency of the other two species Lecanora mutabilis and Lecidea stigmatea is possibly attributable to the similarity of these two species to other crustose lichen species. Frequently the heterogeneity of morphological characteristics makes species separation difficult if not impossible. The frequency values of all other prevalent species were not statistically different from year to year as determined with Fisher's mean separation test and Analysis of Variance (ANOVA).

A list of lichen species encountered at each of the 18 stands is given in Table 3.4-14 with their frequency by year and an average frequency for the three sampling years.

3.4.6 Soil Microbiology and Soil Chemistry

Sampling for soil microbiology and chemistry occurred in January, April, July, and October 1984 along transects at eight sites within or adjacent to oil shale tracts Ua and Ub (Figure 3.3-1). Soils were collected as in previous years.

All samples were sieved using a 2 mm screen and analyzed for moisture

Table 3.4-14 Frequency of all lichen species encountered with frequency values for each year and average of 3 years. Listed in descending order of average frequency.

Species	82	83	84	Avg.	S.D.
Acarospora strigata	0.81	0.77	0.94	0.84	0.0893
Canderlariella rosulans	0.77	0.88	0.81	0.78	0.0225
Staurothele rufa	0.68	0.73	0.92	0.77	0.1297
L. caesiosinerea	0.65	0.68	0.70	0.68	0.0252
L. mutabilis	0.61	0.56	0.61	0.59	0.0280
Caloplaca trachyphylla	0.57	0.56	0.61	0.58	0.0265
L. stigmatea	0.42	0.60	0.60	0.54	0.1053
A. smaragdula	0.40	0.37	0.48	0.42	0.0558
L. peltata	0.40	0.33	0.31	0.35	0.0473
Lecidia auriculata	0.23	0.30	0.19	0.24	0.0549
Buellia punctata	0.23	0.08	0.38	0.23	0.1498
L. muralis	0.18	0.22	0.17	0.19	0.0290
L. garovaglii	0.15	0.17	0.17	0.16	0.0117
L. novomexicana	0.16	0.10	0.11	0.13	0.0313
A. glaucocarpa	0.13	0.11	0.14	0.12	0.0141
Rhizocarpon disporum	0.10	0.09	0.10	0.10	0.0087
Lecanora alphoplaca	0.11	0.08	0.09	0.09	0.0143
Dermatocarpon miniatum	0.08	0.08	0.07	0.08	0.0039
B. saurina	0.03	0.06	0.07	0.06	0.0225
Sarcogyne privigna	0.10	0.04	0.01	0.05	0.0428
L. melanothalma	0.04	0.05	0.03	0.04	0.0061
Parmelia substygia	0.03	0.05	0.03	0.04	0.0134
Collema sp.	0.04	0.05	0.00	0.03	0.0239
L. calcarea	0.07	0.01	0.00	0.03	0.0378
L. russellii	0.01	0.03	0.04	0.02	0.0159
A. chlorophana	0.01	0.02	0.01	0.01	0.0055
L. chrysoleuca	0.00	0.00	0.01	0.00	0.0033

content, pH, EC, organic carbon, total bacteria, total fungi, total algae, respiration, and dehydrogenase activity. Methods for analyses were identical to those described in the EMM, 1982. Measures of moisture content and microbiological analyses were performed on fresh soils within a week of collection. The pH, EC, and organic carbon assays were performed on air dried samples. Results of the soil analyses for each sampling period are shown in Table 3.4-15. The yearly summary for 1984 for the eight sampling sites is reported in Table 3.4-16. Yearly trends and analyses for all samples in 1984 follow, as well as, comparisons with 1981-1983 data.

3.4.6.1 Soil Moisture Content. Mean soil moisture content (all sites, all depths) fluctuated from a January high of 24.3% to a July low of 6.9% (Table 3.4-15, Figure 3.4-5). During summer months, moisture levels were slightly higher in surface (0-5 cm) soils than in subsurface soils (5-15 cm) unlike past years when subsurface soils were slightly higher. In winter months, surface soils generally contained 5-10% more moisture than subsurface soils. There are significant differences in soil moisture content between months but not sites (Table 3.4-15 and 16). Unlike the 1983 data, riparian soils (VR1) did not have more moisture than upland soils. Site VS1 had the highest average moisture content with 20.8% followed by VJ5(17.0%), VG1 (16.4%), VR1 (16.0%), VJ1 (15.8%) and VS4 (15.5%). Sites VG2 and VG3 had the lowest average soil moisture content on an annual basis, averaging 13.6% and 12.3%, respectively. These patterns are quite different from those found in 1981-1983 with 1984 moisture levels being generally 3-4% higher than those recorded in 1982 or 1983. A major difference in 1984 was the high soil moisture levels for the July and October sampling.

Table 3.4-15 Monthly means for chemical and microbiological characteristics of WRS soils. Values are averages for all transects and soil depths sampled during the given month in 1984. Values followed by common letters are not significantly different as tested by ANOVA and Fishers LSD separate tests ($F \leq .05; \alpha \leq .05$).

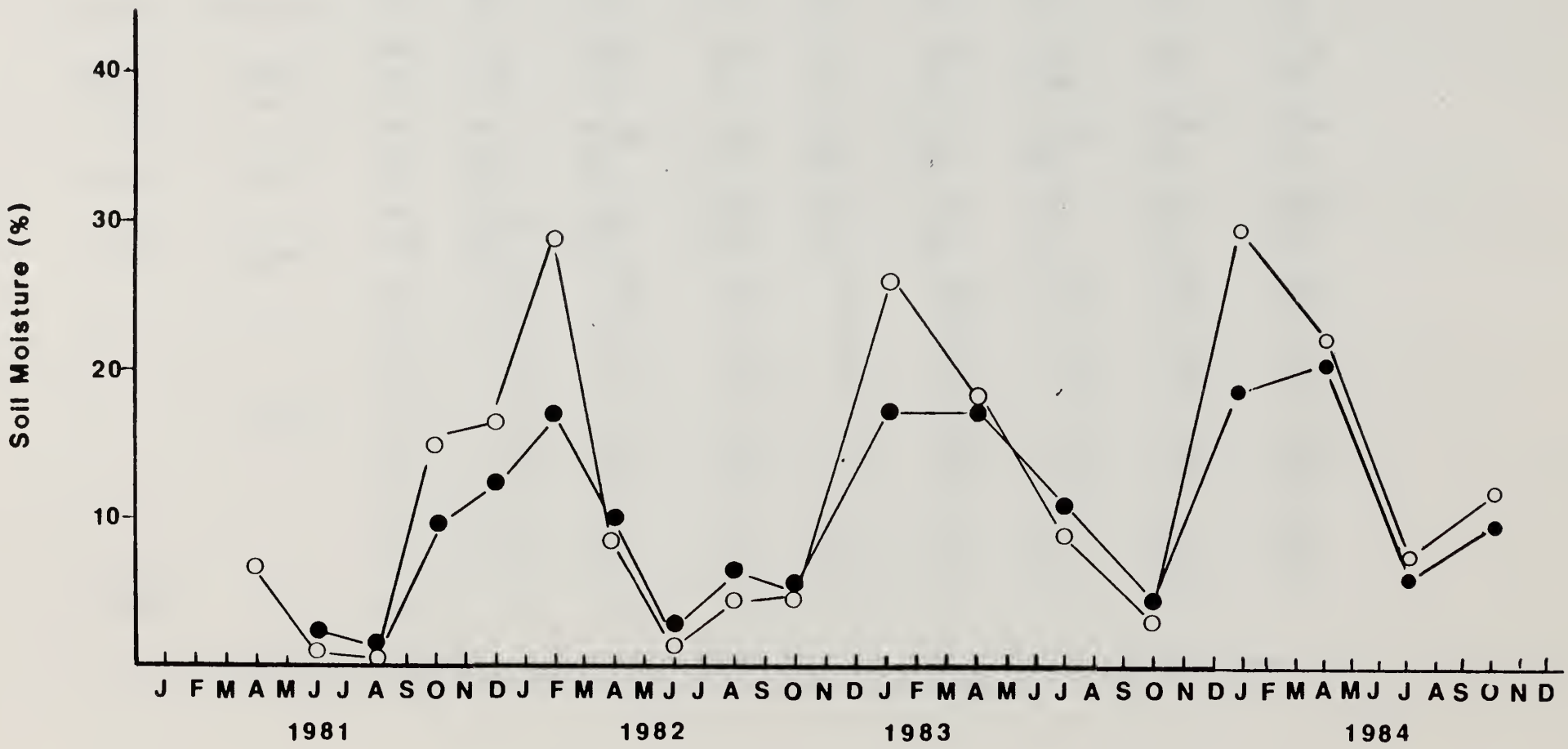
Variable	Unit	January	April	July	October
Moisture	%	24.3^{a}	21.7^{b}	6.9^{c}	10.8^{d}
pH		7.60^{a}	8.09^{c}	7.76^{b}	7.76^{b}
EC	$mmho/cm^2$	0.22^{a}	0.24^{a}	0.23^{a}	0.26^{a}
Organic Carbon	%	0.97^{a}	1.06^{a}	0.44^{b}	1.47^{c}
Total Bacteria	10^6 CFU/g	21.9^{bc}	24.9^{c}	12.6^{a}	14.8^{ab}
Total Fungi	m hyphae/g	23.3^{b}	40.3^{c}	12.8^{a}	30.3^{b}
Total Algae		562^{a}	700^{a}	683^{a}	455^{a}
Diatoms		495^{ab}	269^{a}	807^{b}	500^{ab}
Respiration	10^{-4} meq CO_2/g/hr	6.6^{b}	5.0^{a}	4.0^{a}	4.3^{a}
Dehydrogenase	mg formazan/liter	7.4^{a}	7.3^{a}	7.2^{a}	8.4^{a}

Table 3.4-16 Yearly summary by site and depth of the soil and microbiological data taken during 1984. Mean values followed by common subscripts are not significantly different as tested by ANOVA and Fisher's LSD with $F \leq .01$ and $\alpha \leq .05$.

Variable	Unit	Depth	VS1	VS4	VG1	VG2	VG3	VJ1	VJ5	VR1
Moisture	%	0-5	22.3	16.9	19.5	15.2	14.4	17.2	20.4	17.8
		5-15	19.2	14.2	13.3	12.0	10.3	14.3	13.6	14.1
		AVG.	20.8^{a}	15.5^{a}	16.4^{a}	13.6^{a}	12.3^{a}	15.8^{a}	17.0^{a}	16.0^{a}
pH		0-5	7.60	7.85	7.71	7.74	7.76	7.70	7.84	7.80
		5-15	7.72	7.99	7.78	7.76	7.88	7.80	7.98	7.92
		AVG.	7.66^{a}	7.92^{c}	7.74^{ab}	7.75^{ab}	7.82^{abc}	7.75^{ab}	7.91^{bc}	7.86^{bc}
EC	mmho/cm	0-5	.30	.24	.23	.20	.28	.19	.26	.36
		5-15	.25	.22	.18	.16	.22	.18	.23	.30
		AVG.	$.27^{c}$	$.23^{bc}$	$.20^{ab}$	$.18^{a}$	$.25^{c}$	$.18^{a}$	$.24^{bc}$	$.33^{d}$
OC	%	0-5	1.60	.85	.79	.66	.92	1.15	1.20	1.98
		5-15	1.26	.68	.64	.52	.62	.89	.90	1.14
		AVG.	1.43^{d}	$.77^{abc}$	$.71^{ab}$	$.59^{a}$	$.77^{abc}$	1.02^{bc}	1.05^{c}	1.56^{d}
Bacteria	10^{6}CFw/g	0-5	31.3	20.7	19.7	17.9	45.2	8.2	14.5	27.9
		5-15	25.3	14.7	12.2	12.2	13.9	8.2	11.2	13.5
		AVG.	28.3^{cd}	17.7^{abc}	16.0^{ab}	15.1^{ab}	29.5^{d}	8.2^{a}	12.9^{ab}	20.7^{bcd}
Fungi	m hypae/g	0-5	30.1	19.5	21.7	18.8	16.4	23.6	26.3	27.4
		5-15	54.9	37.6	14.3	16.9	14.8	41.2	34.8	13.5
		AVG.	42.5^{e}	28.5^{abcd}	18.0^{ab}	17.8^{ab}	15.6^{a}	32.4^{cde}	30.6^{bcde}	27.7^{abc}
Respir-ation	10^{-4} meq CO_2/g/hr	0-5	8.5	5.7	5.0	4.1	6.3	3.28	6.6	6.5
		5-15	5.0	4.1	3.3	3.7	3.6	5.25	4.7	3.9
		AVG.	6.8^{c}	4.9^{ab}	4.1^{ab}	3.9^{a}	5.0^{ab}	4.3^{ab}	5.6^{bc}	5.2^{abc}
Dehydro-	mg formazan/ liter	0-5	13.8	8.9	10.4	8.7	10.9	9.6	9.9	12.3
		5-15	6.0	3.4	4.1	4.5	4.9	6.2	4.7	2.9
		AVG.	9.9^{a}	6.2^{a}	7.2^{a}	6.6^{a}	7.9^{a}	7.9^{a}	7.3^{a}	7.6^{a}
Algae		*	1862^{d}	1378^{c}	746^{b}	1121^{c}	1270^{c}	1191^{c}	1424^{c}	248^{a}
Diatoms		*	1581^{d}	1172^{c}	745^{b}	1103^{c}	890^{b}	1555^{d}	1201^{c}	30^{a}

*Only soils taken at 0-5 cm depth were analyzed.

Figure 3.4-5. Monthly mean moisture contents for 0-5 cm (O) and 5-15 cm (●) soils. All sites are included. Results for 1981 - 1984 are compared.



The July values were six times the 1983 July value and the October samples were double that of 1983.

3.4.6.2 pH and EC. Soil pH's averaged 7.76 in the 0-5 cm zones and 7.85 in the 5-15 cm zones of soils on tract but the difference was not significant. The slightly lower values of the surface soils may reflect their higher organic matter contents. There were also significant differences in soil pH between transects and sampling dates (Tables 3.4-15 and 16). Sites VS4 had a significantly higher pH value than all but two of the other seven sites. April samples had consistently higher pH values than the other samples while the January samples were significantly lower. These results are consistent with those measured in 1981-1983 (Figure 3.4-6) although there appears to be a slight overall decline in the pH, which may be due to greater than average precipitation the past two years.

Electrical conductivities of the soils sampled averaged 0.24 $\pm$ 0.09 mmhos/cm (all transects, depths, and dates). There were no significant differences in EC between sampling dates (Table 3.4-15 and 16) but there were differences among sites and between sample depths. Soils from the riparian site (VR1) had the highest ECs (.33), presumably reflecting salt accumulation from surface evaporation (Figure 3.4-7). Soils from the surface (0-5 cm) had significantly higher EC values (.257) than subsurface soils (5-15 cm) which averaged .215.

3.4.6.3 Organic Carbon. Organic carbon contents averaged 0.83 in 0-5 cm soils and 1.15% in 5-15 cm soils on the Ua and Ub tracts. The 1984 levels were more closely aligned to those in 1982 and 1983. The riparian site had the

Figure 3.4-6. Average pH values for all sites and depths for 1981 - 1984.

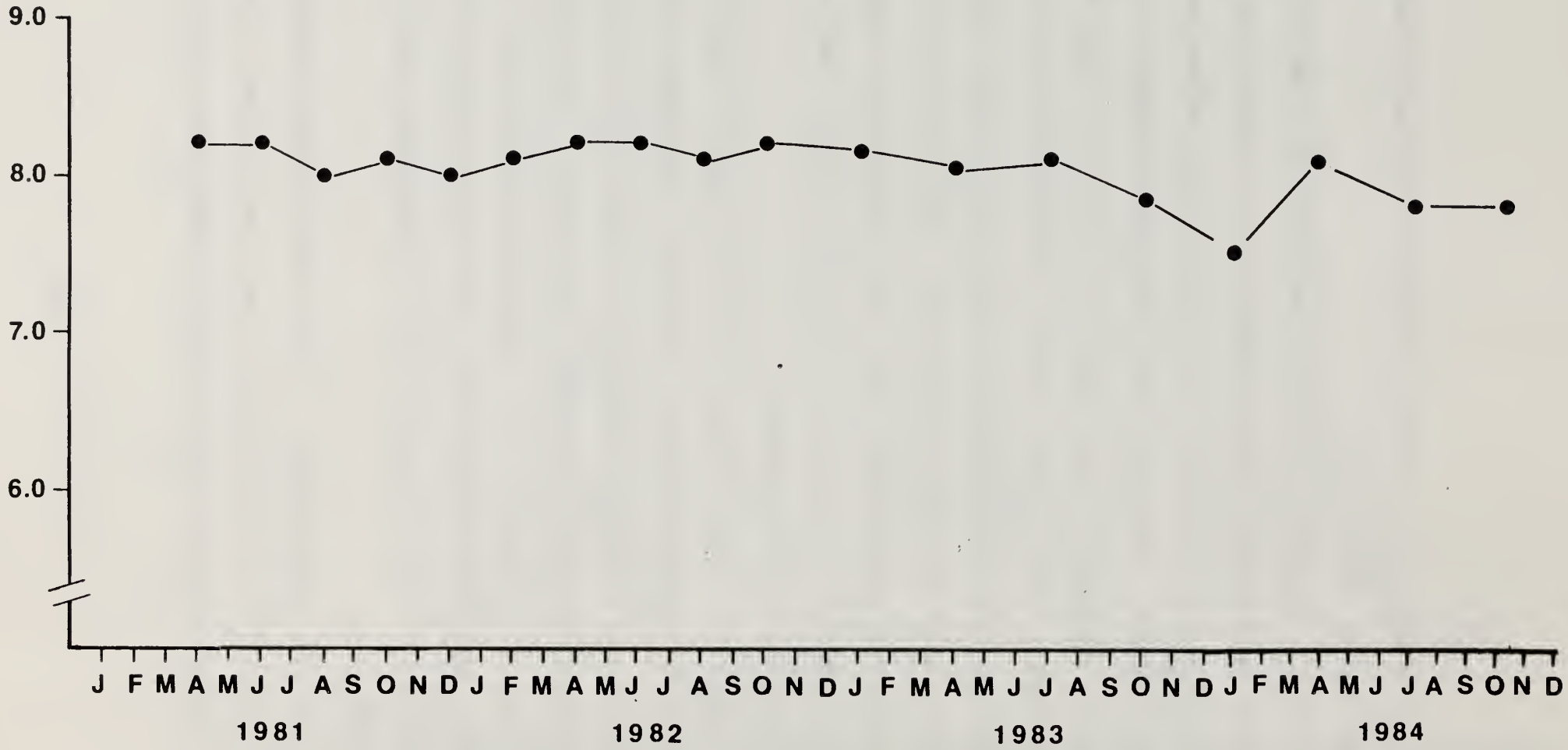
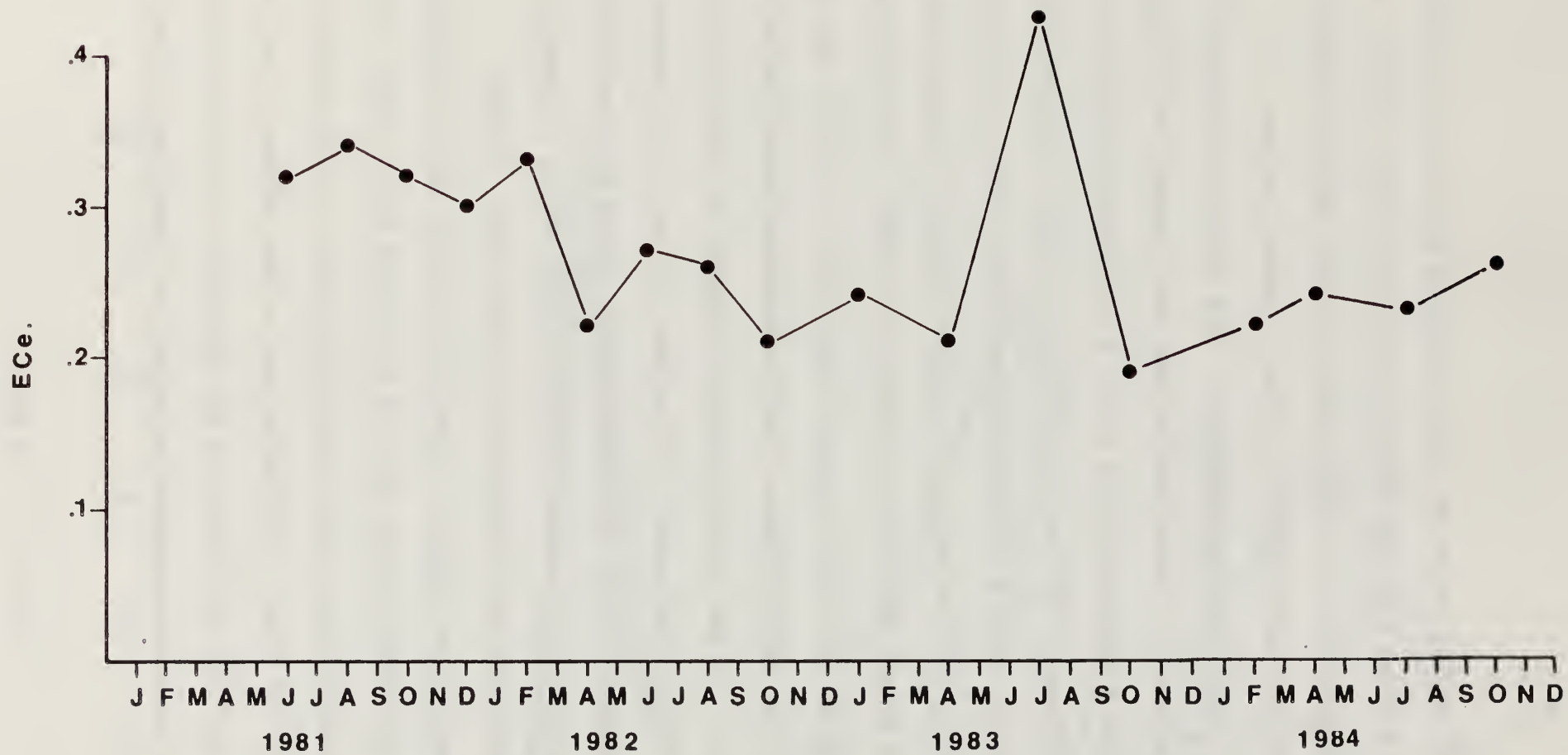


Figure 3.4-7. Average EC values for all sites and all depths for 1981 - 1984.



highest organic carbon values at 1.56% and along with site VS1 were significantly greater than the other upland sites (Table 3.4-16). Soils collected during the fall had significantly higher levels of organic carbon than soils collected during the winter, spring or summer periods.

3.4.6.4 Total Fungi and Bacteria. Soil bacteria fluctuated in an annual cycle characterized by a winter-spring peak and a summer low (Figure 3.4-8). In 1984, counts hit a maximum of 24.9 $\pm$ 17.0 x 10^6 CFU/g (all sites, all depths) in April and a minimum of 12.6 $\pm$ 1.9 x 10^6 CFU/g in July. January and October values fell in the 15-22 x 10^6 CFU/g range (Table 3.4-15). This cycle replicates fairly well the values obtained for 1982-83 (Figure 3.4-8), however, the top of the winter peak was not sampled as in 1982. The April sample was also closer to the 1983 level and much higher than in 1981 or 1982 as was the case with the soil moisture data. Factors governing these fluctuations will be discussed later. On the average, bacterial counts for subsurface (5-15 cm) soils were 50% lower than counts for surface (0-5 cm) soils, however, the difference decreased during the summer months. Sites differed significantly in bacterial populations with sites VG3, VS1 and VR1 having a higher number of bacterial populations than the other five sites (Table 3.4-16).

Fungal populations peaked in 1984 in the spring and fall samples (Figure 3.4-9). The July samples were very low as was the case in 1983. Subsurface (5-15 cm) populations were consistently higher than surface populations averaging about 20% more. Differences were evident between sites, with the juniper (VJ1 and VJ5) sites and site VS1 supporting generally high populations of fungi. The sagebrush-greasewood sites had the lowest population of fungi.

Figure 3.4-8. Yearly cycle of total bacteria for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1984.

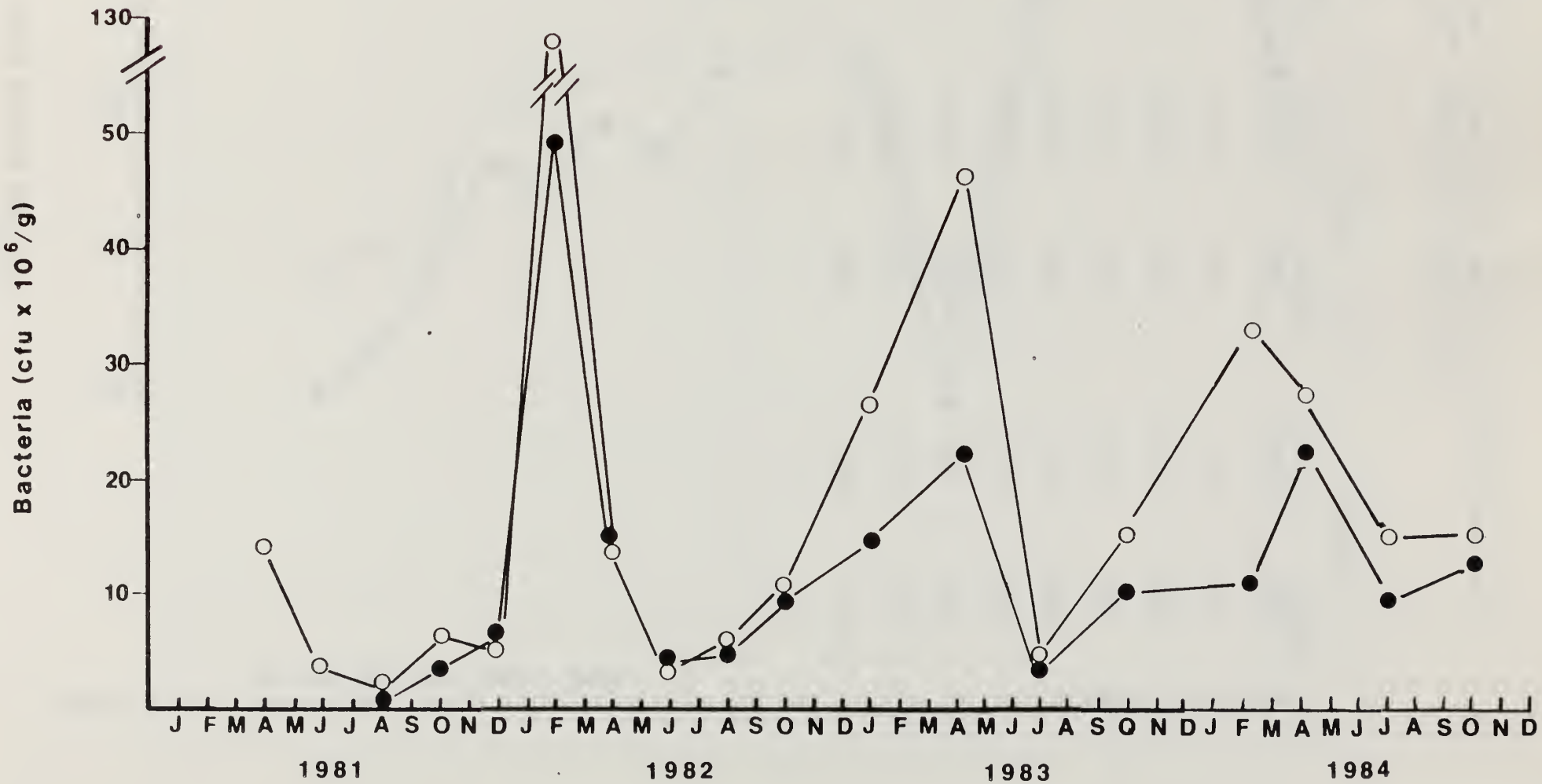


Figure 3.4-9. Monthly mean fungi value for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1984.

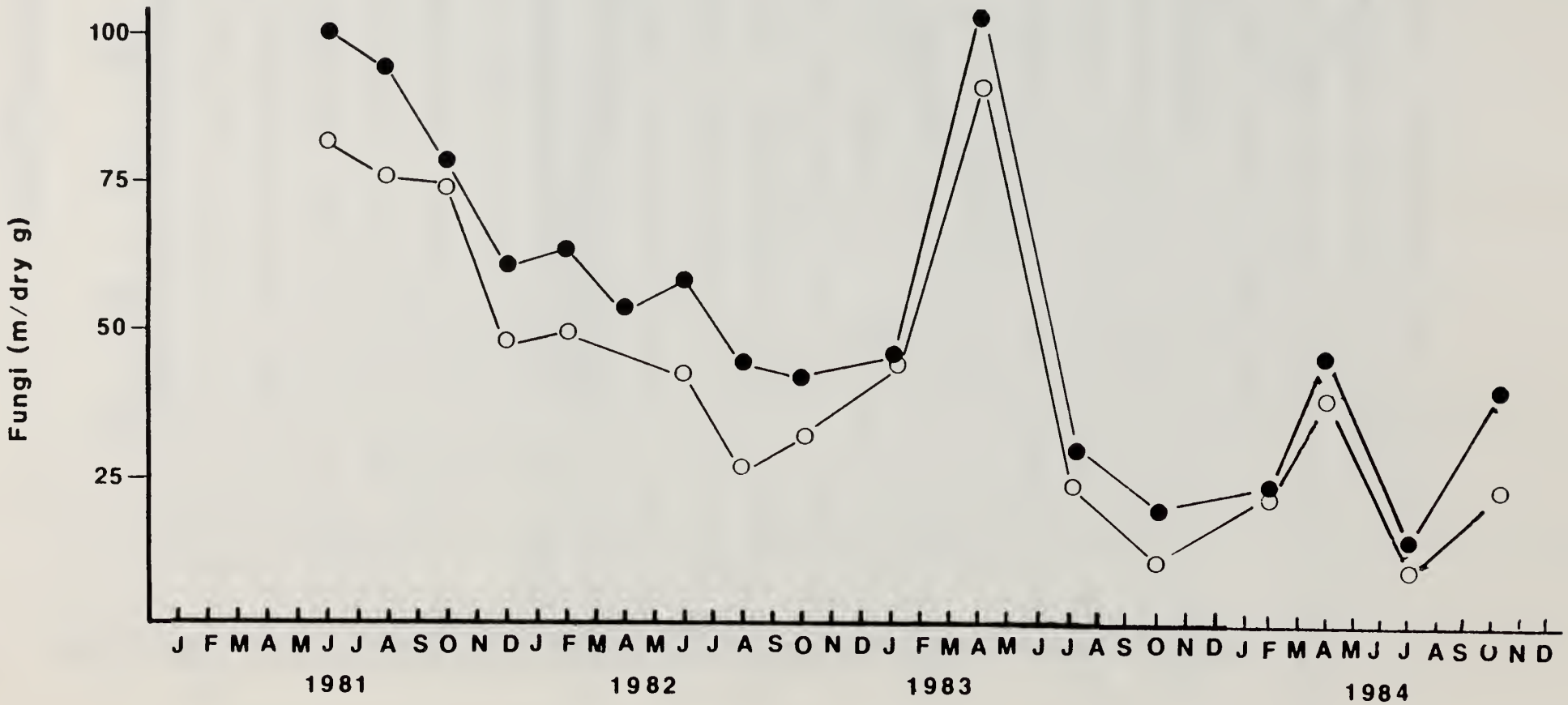


Table 3.4-17 Direct algal counts for the October soil samples for eight sites.

	Algae		Diatoms	
Transect	October 1983	Average 1984	October 1983	Average 1984
V61	797	746	498	745
V62	1282	1211	1113	1103
V63	2137	1270	1584	890
VJ1	1623	1191	943	1555
VJ5	967	1424	995	1201
VS1	602	1862	431	1581
VS4	1480	1378	902	1172
VR1	562	248	170	30

3.4.6.5 Total Algae. Results of the direct algal counts are presented in Table 3.4-17. Algae were divided into single celled algae and diatoms. Since fluorescence microscopy was used all counts were of living material and in the case of diatoms not diatom frustules as is common in other sampling methods. Filamentous algae were so rarely encountered that they were dropped from the analyses.

Seasonal trends and differences between vegetation types are reported in Table 3.4-17. Single celled algae show a peak in April with a low in October (Figure 3.4-10). The 1984 October sample is much lower than that obtained during 1983. The reason for this is unknown. Diatoms respond quite differently than single celled algae. They ' ve a summer peak of 807/g of soil with an April low of 269/g of soil (Figu . 3.4-11).

3.4.6.6 Respiration and Del drogenase Activities. Mean rates of respiration in the soils showed a annual cycle characterized by a January high of 6.6 $\pm$ 4.5 meq CO_2 x 10^{-4}/g/ hr and a July low of 4.0 $\pm$ 1.9 meq CO_2 x 10^{-4}/g/hr. Surface and subsurface soils followed similar patterns (Table 3.4-15, Figure 3.4-12) although subsurface soils are significantly lower in respiration than surface soil (30%). There are also significant differences in soil respiration between sites with the VS1 site having significantly higher respiration rates than all other sites except VR1 and VJ5 (Table 3.4-16). Site VG2 had the lowest values.

Respiration values for 1984 continued to show an annual cycle of a winter high and summer low, as was the pattern in 1982-83. Due to the wet summer soils had higher rates during the July samples in 1984 compared to 1982 or 1983.

Figure 3.4-10. Monthly mean algae counts for 0-5 cm soil depth. All sites included for October 1983 to October 1984.

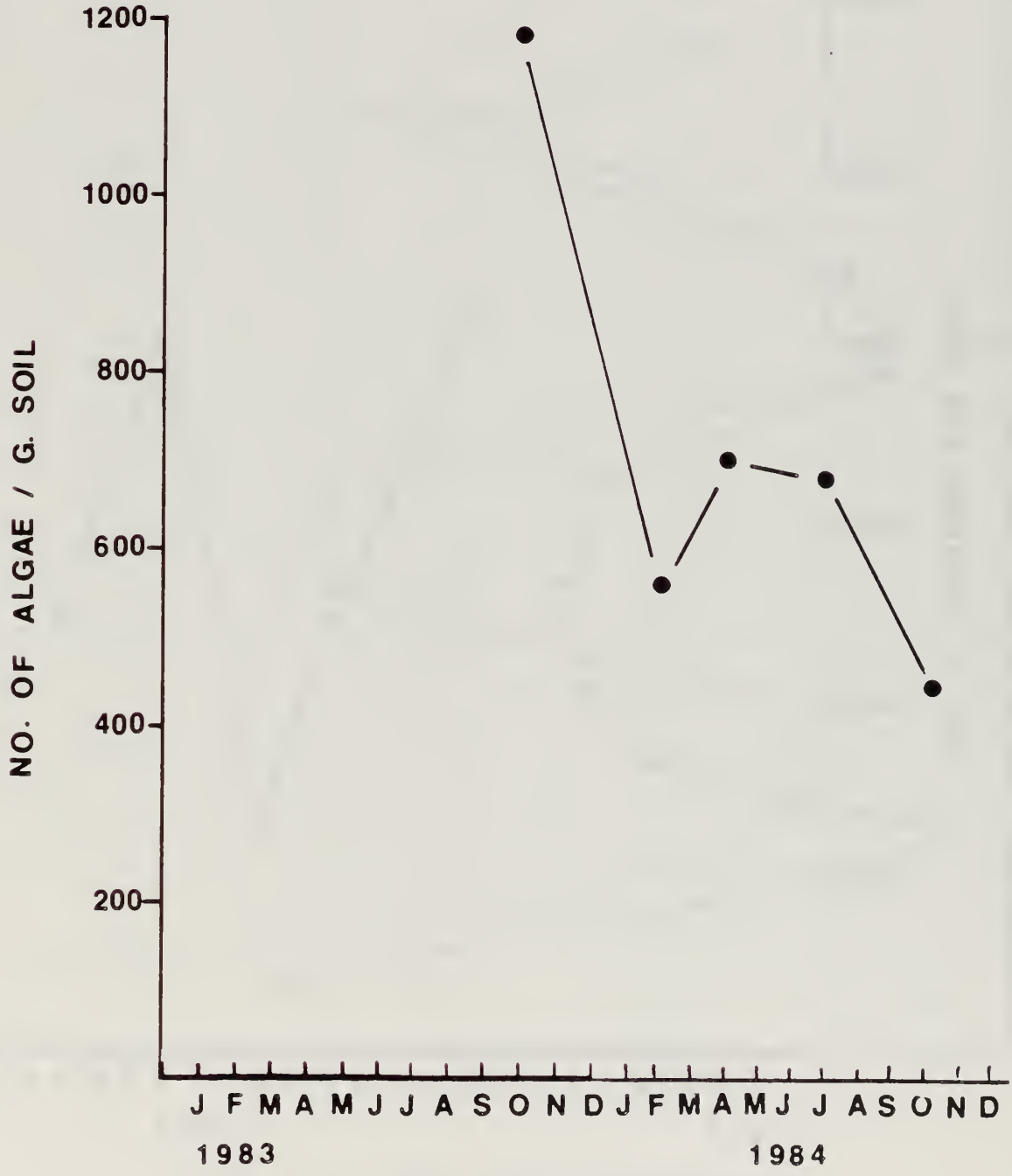


Figure 3.4-11. Monthly mean diatom counts for 0-5 cm soil depth. All sites included for October 1983 to October 1984.

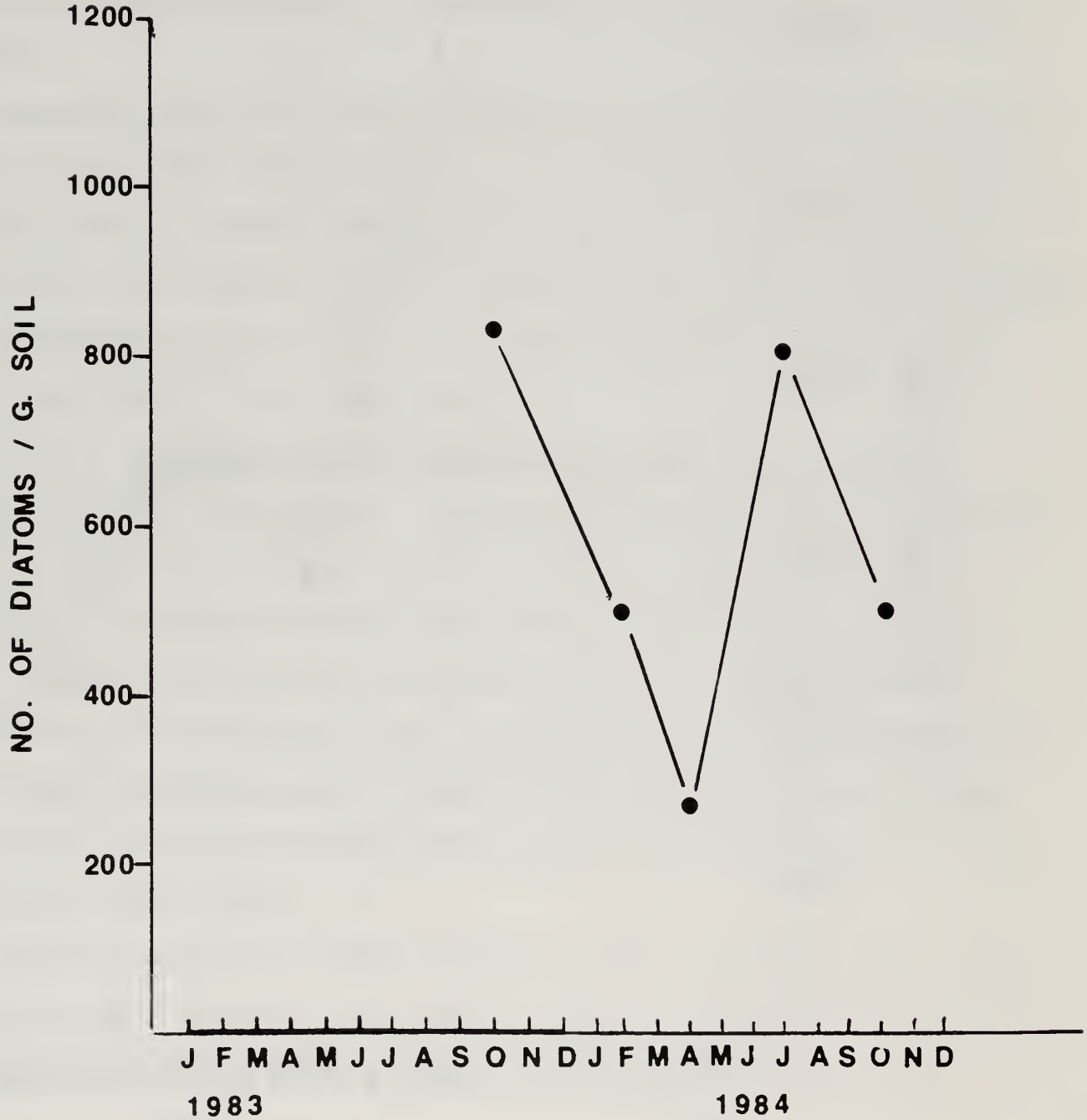
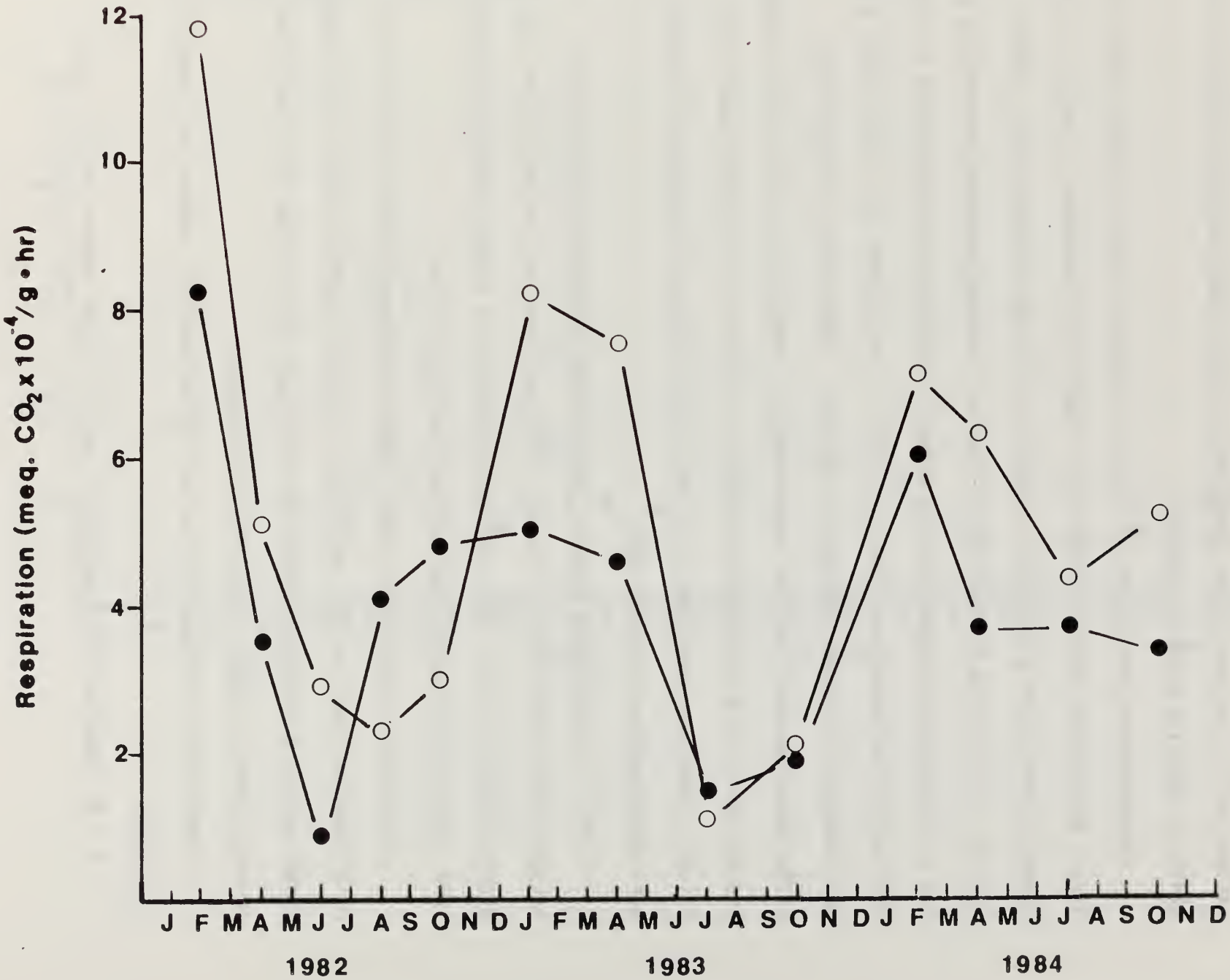


Figure 3.4-12. Monthly mean respiration for 0-5 cm (O) and 5-15 (●) soil depth. All sites are included for 1981 - 1984.



Surface soils also had higher respiration rates than subsurface soils in July which is opposite that of 1982-83.

Dehydrogenase activities in the soil sampled showed no annual pattern in 1984. Mean values (all transects, all depths) hit minimums in July at 7.2 mg formazan/liter, and a maximum in October of 8.4 mg formazan/liter, (Table 3.4-15). Soils from the two depth intervals behaved somewhat differently with the surface materials consistently showing 10-30% more dehydrogenase activity than subsurface materials (Figure 3.4-13). The surface soil also showed a small but consistent increase throughout the year. There were no significant differences between sites for dehydrogenase although site VS1 had the highest average value (919 mg formazan/liter), and site VS4 having the lowest (Tab 3.4-16). This was consistent with 1983 data although significant differenc were noted between sites in 1983.

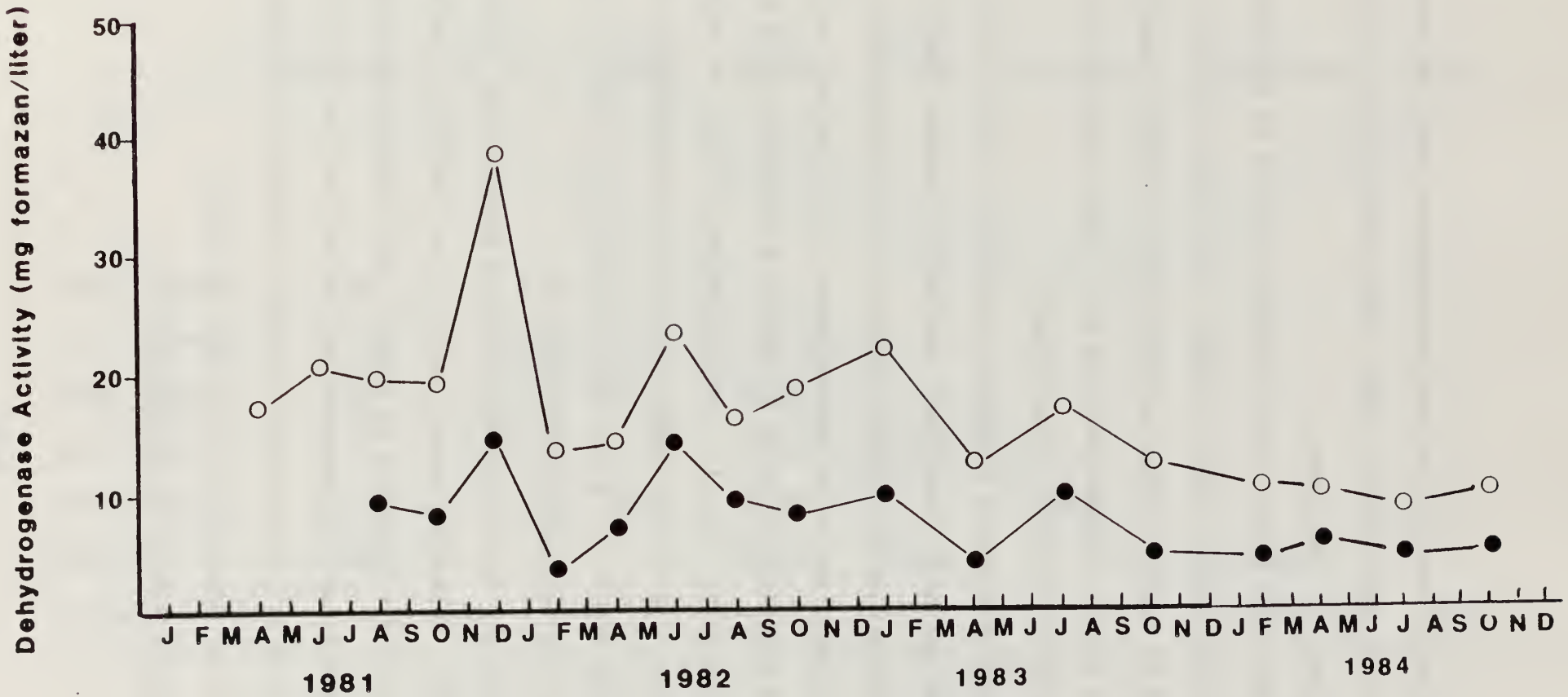
3.4.6.7 Correlation between Chemical And Microbiological Factors. Co re-lation coefficients linking the ten variables measured for White River soils are given in Table 3.4-18. This analysis includes all samples collected during 1984. Only relationships for which $\alpha \leq 0.01$ are listed.

Correlation coefficients among chemical parameters are similar to the relationships found in 1981 and 1983. The finer textured soils, with generally higher moisture contents, tended to have lower pH's, higher EC's and higher organic carbon contents (see 1982 final report).

Coefficients linking chemical and microbiological properties showed the following:

1. As expected, high bacterial counts, fungal hyphae lengths, algae

Figure 3.4-13. Monthly mean dehydrogenase activities for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1983.



counts, microbial respiration and dehydrogenase levels were associated with relatively moist soils. Water stress typically limits microbial growth activity in arid areas.

2. Bacterial and fungi numbers and activities tend to be positively correlated with organic matter content. Soils that are rich in organic matter tend to support larger and more active microbial populations. Again, this result is expected since soil organic matter is the primary energy source for microbial populations.

Correlations among microbiological parameters indicated strong positive relationships between bacterial counts and respiration, between fungal counts and respiration, and association between respiration and dehydrogenase. Also, algae was positively associated with dehydrogenase, total bacteria and fungi.

In general, the coefficients given in Table 3.4-18 are low ($\pm$ 0.2-0.5), but this is not surprising given that all sampling periods, sites, and depth intervals are included. As in 1981-1983 correlation coefficients for soils collected from a given depth on a given date were generally higher ($\pm$ 0.4-0.6) but the significance ratings were not different.

Most 1984 results are statistically similar in magnitude to results obtained in 1981-1983. Repeating annual cycles in soil moisture, bacterial counts, and respiration are beginning to appear. Most parameters being measured are significantly correlated with one another, and most of the correlations make biological sense. This is evidence that a coherent package of variables have been chosen and that our measurement techniques are sound.

3.4.7 Revegetation Success on Disturbed Sites

Table 3.4-18 Correlation coefficients linking chemical and microbiological parameters for tracts Ua and Ub soils. All 252 samples collected in 1984 are included in this analyses. Only relationships for which $\alpha \leq .01$ are listed.

	Moisture	pH	EC	Organic Carbon	Total Bacteria	Total Fungi	Respiration	Dehydrogenase	Algae
Moisture									
pH									
EC									
Organic carbon	0.31		0.59						
Total Bacteria	0.34		0.27	0.17					
Total Fungi	0.29			0.31	0.29				
Respiration	0.47		0.34	0.39	0.40	0.40			
Dehydrogenase	0.23		0.44	0.48	0.34		0.43		
Algae	0.20				0.26	0.25		0.46	
Diatoms		-.18						0.32	0.77

Figure 3.4-14 Areas revegetated in 1982 along main mine access road. Area begins at the Watson road turnoff and continues to the end of the pavement.

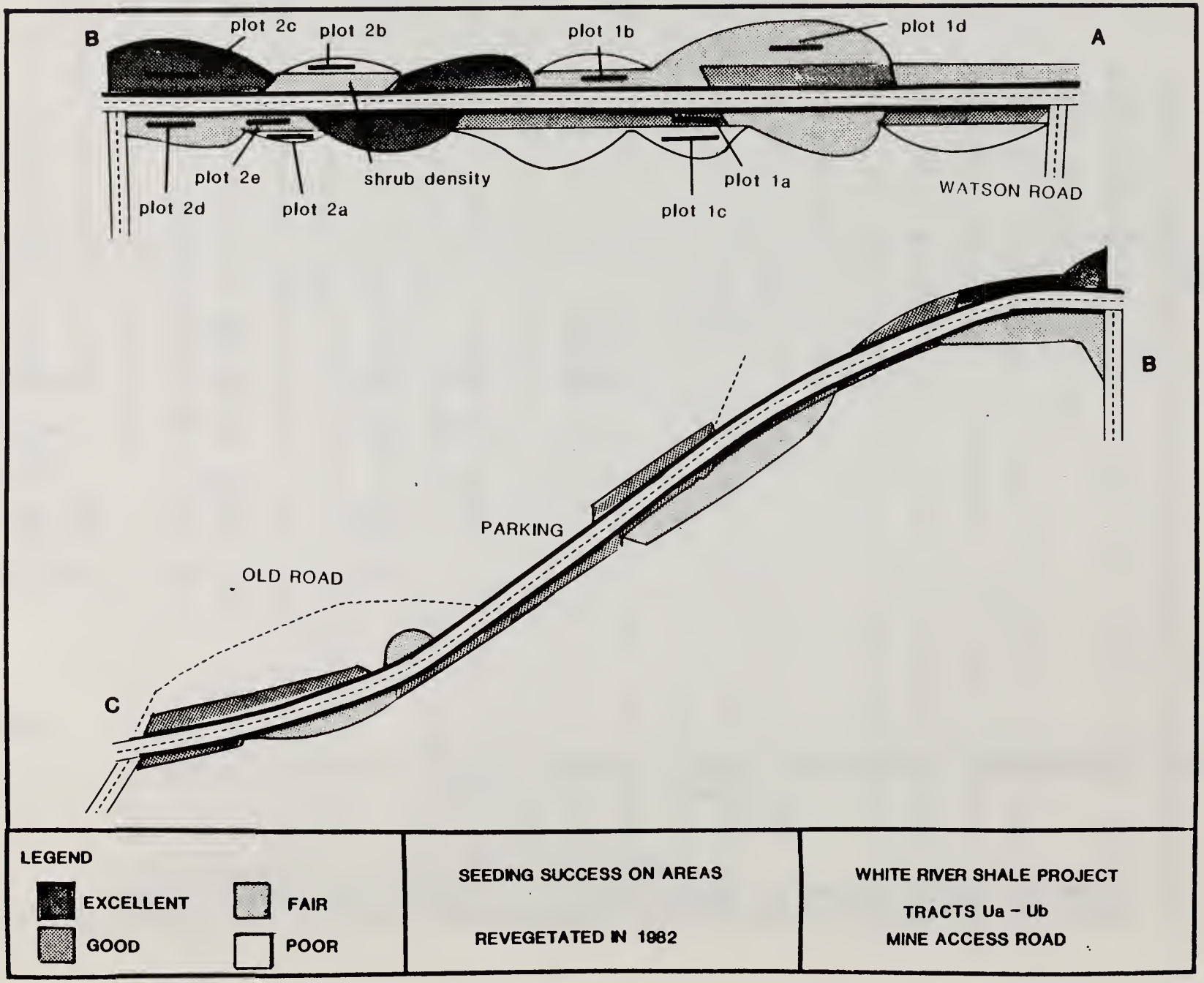
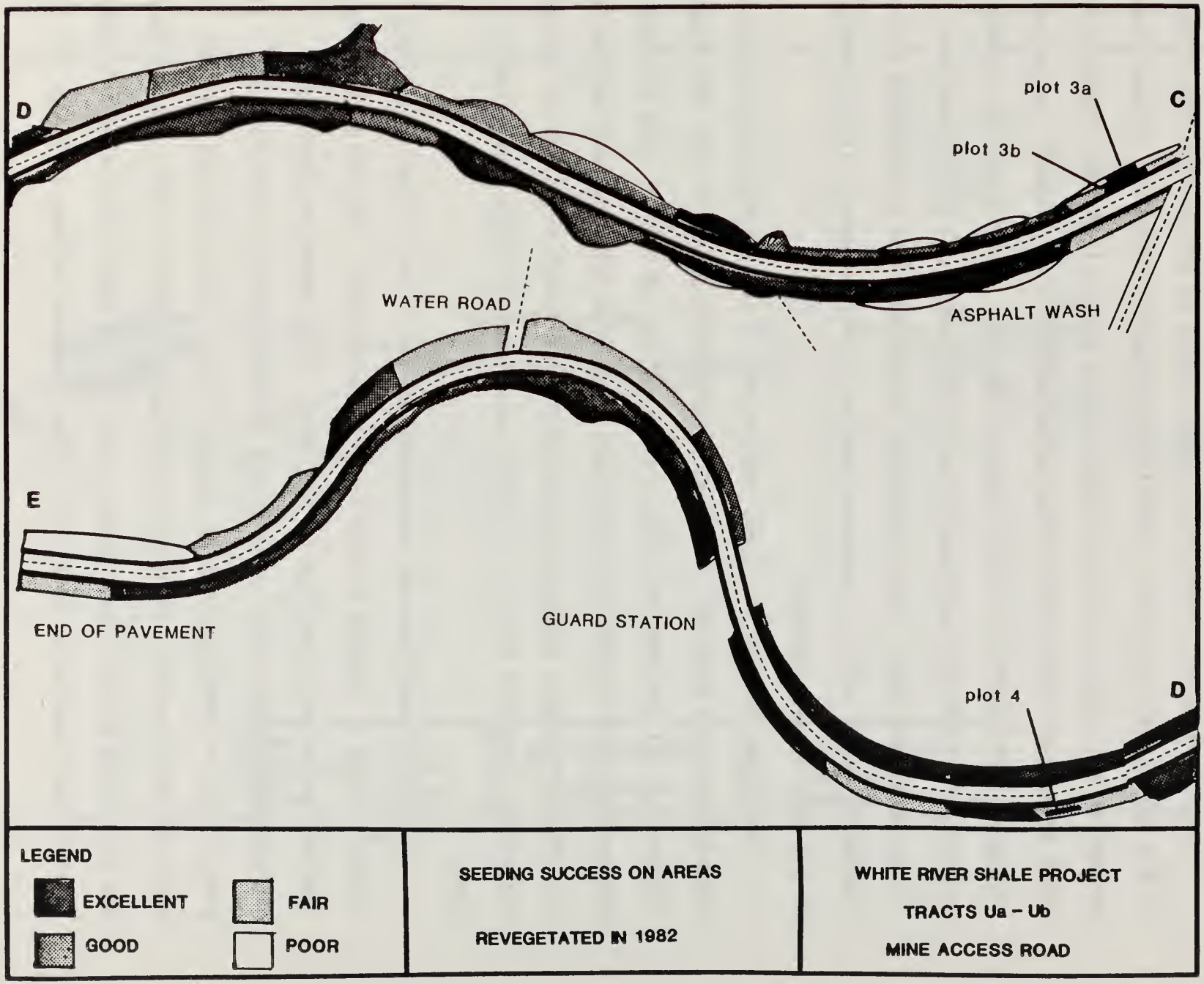


Figure 3.4-14 Continued



Several disturbed areas on oil shale tracts Ua and Ub have been revegetated in the last couple of years. Roadside disturbances along the highway from Bonanza to the plant site were revegetated in the fall of 1982 (Figure 3.4-14). Other areas near the retention dam, water well road and topsoil stockpiles were revegetated in the fall of 1983 (Figure 3.4.-15). Areas along the highway reclaimed in 1982 were hydroseeded and drill seeded. In a few locations transplants were used. Areas reclaimed in 1983 were all hydroseeded with either a permanent seed mix or a temporary seed mix. Approximately 14,000 transplants of six species were planted.

Four sites between Duck Rock and the end of the pavement going south towards the plant site were selected as monitoring sites for the 1982 seedings (Figure 3.4-14) and were evaluated in the spring and fall of 1983 and 1984. Monitoring plots for the 1983 reclaimed areas were selected near the dam, along the dam access road, adjacent to the water well access road, and on two topsoil stockpiles (Figure 3.4-15). All plots were sampled in the spring and fall of 1984.

Density of seedlings was determined at each site by placing quadrats ($0.25m^2$) along a transect traversing the seeded area. The distance between quadrats varied with the size of the stand. The number of seedlings encountered in each $0.25m^2$ quadrat was recorded either by lifeform i.e., shrub, grass, forb, or when possible by species. Total cover estimates were not made until at least one year after seeding occurred. Shrub density was determined at one site along the main mine access road for the 1982 transplants and transplant survival was recorded at four plots along the water access well road for the

Figure 3.4-15 Areas revegetated in 1983. Map A - Water well access road. Map B - Mine area. Map C - Retention Dam Area.

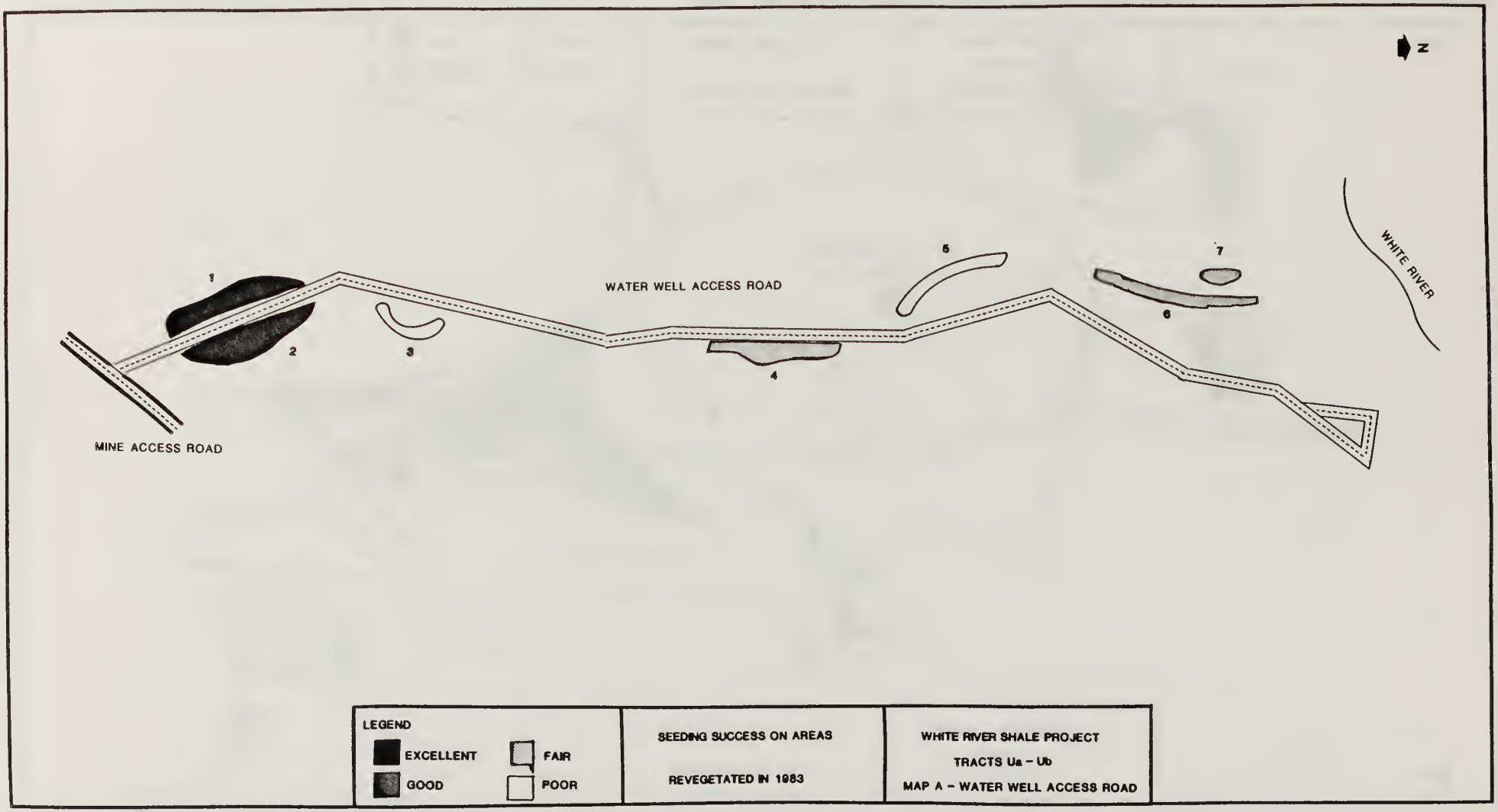


Figure 3.4-15 Continued

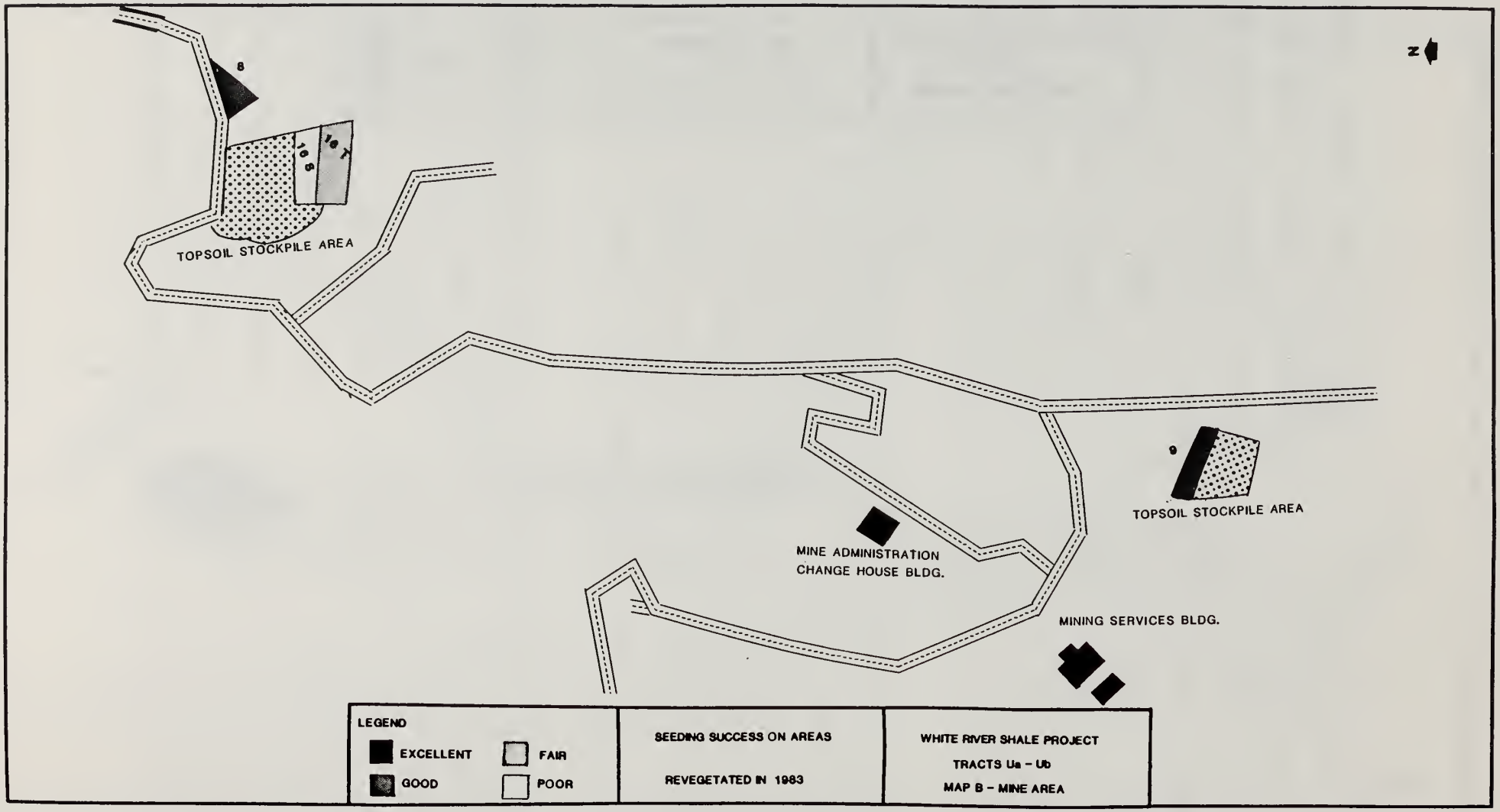
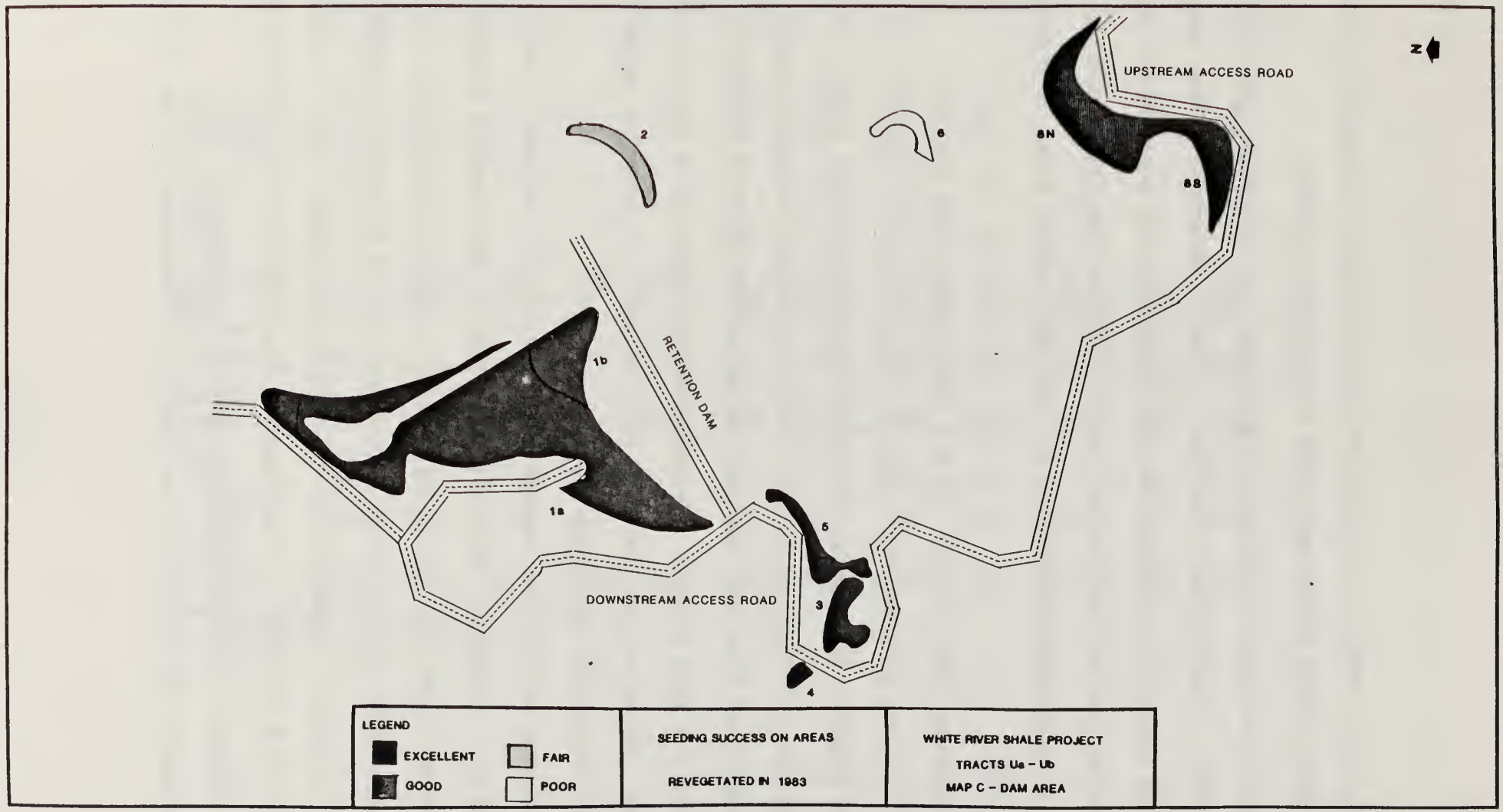


Figure 3.4-15 Continued



1983 plantings. Density estimates were used to assess revegetation success using a stand rating system described in Vallentine (1974).

Sampling was done in October to determine survival after the critical summer period. Sampling was also done in June to determine winter survival rates. The results by revegetation monitoring plot are presented in Table 3.4-19 for the spring sampling and Table 3.4-20 for the fall sampling. A summary of revegetation monitoring for the 1982 seeding areas is presented in Table 3.4-21.

The average plant density for all 1982 seeded plots was 10.7 plants/m^2 in June of 1984 which would be classified by Vallentine (1974) in the excellent category for seeding success in the Intermountain area. Of the 12 plots sampled, six plots would fall into the excellent category, one into the good category and five into the poor category. Of the 10.7 plants/m^2, 7.0 were grasses and 3.7 were shrubs. The most commonly encountered species was western wheatgrass (averaging approximately 4.9 plants/m^2), followed by sagebrush (2.5 plants/m^2) and Indian ricegrass (2.1 plant/m^2).

By October of 1984 the average plant density for the same plots had decreased to 7.5 plants/m^2 which is classified as good seeding success according to Vallentine (1974). Of the 7.4 plants/m^2, 1.8 were shrubs and 5.7 grasses. Western wheatgrass was still the most common with 4.9 plants/m^2 compared to 4.8 plants/m^2 in June. Sagebrush was the second most common with 1.2 plants/m^2 as compared to 2.5 plants/m^2 in June and 0.6 plants/m^2 of Indian ricegrass was found in October, as compared to 2.1 plants/m^2 in June.

The results of the analysis to evaluate differences that may be due to

Table 3.4-19 Plant density by species at 12 revegetation monitoring plots along main access road to plant site, June 1984. (See Figure 3.4-14 for site locations).

	Spring 1984											
Site No:	1a	1b	1c	1d	2a	2b	2c	2d	2e	3a	3b	4
Treatment	B[1]E[2]	BW	CW	FW	CW	CE	FW	FE	BE	CE	BE	BE
Species:												
ARTR	1		0.5				10		6		0.5	12.5
ATCA	1	1				0.5	1	0.5	1	0.5		3.5
ATCO				0.5								
CHGR							1		0.5	1		
Total Shrub	2.0	1.0	0.5	0.5	0	0.5	12.0	0.5	7.5	1.5	0.5	16.0
AGSM	3	10.5	1	3		0.5	10	1.0	9	2.5	4.5	13
ORHY			4	2	7	5.5	0.5		1.5	2.5	0.5	2
Total Grass	3.0	10.5	5.0	5.0	7.0	6.0	10.5	1.5	10.5	5.0	5.0	15.0
Seeding Success	Fair	Excel	Good	Good	Good	Good	Excel	Poor	Excel	Good	Good	Excel
Cover												
Total	8.6	9.9	2.4	9.9	1.0	12.5	23.1	26.9	10.4	3.4	7.3	14.8
% Perennial	12.8	13.3	2.9	2.4	27.5	1.3	44.9	0.9	27.1	12.0	15.3	43.8
Total Bareground	68.1	69.6	27.0	48.5	8.6	13.8	59.5	53.1	82.9	92.3	85.0	43.8

1-B = Borrow; F = Fill Slope; C = Cut Slope
2-E = East Aspect; W = West Aspect

Table 3.4-20 Plant density by species at 12 revegetation monitoring plots along main access road to plant site, October 1984. (See figure 3.4-14 for site locations).

	Fall 1984											
Site No:	1a	1b	1c	1d	2a	2b	2c	2d	2e	3a	3b	4
Treatment	B[1]E[2]	BW	CW	FW	CW	CE	FW	FE	BE	CE	BE	BE
Species:												
ARTA	2.5						3.5			3	3	2.5
ATCA	0.5						1	0.5				2
ATCO				1		0.5			0.5			
CHGR							1.5			1	0.5	
Total Shrub	3.0	0	0	1	0	0.5	6.0	0.5	0.5	4.0	3.5	4.5
AGCR		0.5										
AGSM	6.5	7.5		1			7.5		10	2	6	17
ORHY	1.5	1	0.5				0.5		0.5			3.5
Total Grass	8.0	9.0	0.5	1	0	0	8.0	0	10.5	2	6	20.5
Seeding Success	Excel	Excel	Poor	Poor	Poor	Poor	Excel	Poor	Excel	Good	Excel	Excel
Cover												
Total	17.3	21.3	6.0	36.9	6.8	9.9	54.4	37.5	33.8	11.3	16.3	40.6
% Perennial	70.4	6.5	2.5	3.8	0	0.1	17.0	5.6	18.9	17.0	59.0	21.3
Total Bareground	71.8	64.6	14.8	31.5	2.3	15.5	26.9	33.8	54.3	77.3	25.3	34.9

1-B = Borrow; F = Fill Slope; C = Cut Slope
2-E = East Aspect; W = West Aspect

Table 3.4-21 Two year summary of vegetative cover and plant density on areas seeded in 1982 adjacent to main access road to plant site.

	Fall 1983	Spring 1984	Fall 1984
ARTR	4.0	2.5	1.2
ATCA	0.8	0.8	0.3
ATCO	0.8	<0.1	0.2
CHGR	0.3	0.2	0.3
Total Shrubs	5.7	3.7	1.8
AGCR	--	0	<0.1
AGSM	3.0	4.9	4.8
ORHY	0.4	2.1	0.6
Total Grass	4.0	7.0	5.7
Seeding Success	Excel	Excel	Excel
Cover			
Total	7.5	11.2	24.4
% Perennial	--	2.0	4.5
Total Bareground	67.8	55.1	42.7

Table 3.4-22 Vegetative cover and plant density on different treatments along main access road to plant site. (See figure 3.4-14 for locations).

	Cut			Fill			Borrow		
	Fall 83	Spring 84	Fall 84	Fall 83	Spring 84	Fall 84	Fall 83	Spring 84	Fall 84
ARTR	1.2	0.1	0.8	10.8	3.3	1.2	2.1	4.0	1.6
ATCA	0.4	0.3	--	1.2	0.5	0.5	0.8	1.3	0.5
ATCO	0.1		0.1	0.4	0.2	0.3	0.1	--	0.1
CHGR	0.1	0.3	0.1	0.9	0.3	0.5	0.4	0.1	0.1
Total Shrub	1.8	0.7	1.1	13.3	4.3	2.5	3.4	5.4	2.3
AGCR	--	--	--	--	--	--	--	--	0.1
AGSM	2.3	1.0	0.5	2.5	4.8	2.8	3.8	8.0	9.4
ORHY	0.1	4.8	0.1	0.3	0.8	0.2	0.6	0.8	1.2
UNK	0.8			1.5			0.3		
Total Grass	3.2	5.8	0.6	4.3	5.6	3.0	4.7	8.8	10.7
Seeding Success	Fair	Good	Poor	Excel	Excel	Good	Excel	Excel	E[illegible]el
Cover									
Total	1	4.8	8.5	1.4	20.0	42.9	20	10.2	2[illegible].8
% Perennial	--	0.2	0.5	--	7.0	4.2	--	2.6	[illegible].6
Total Bareground	98.4	35.4	27.4	29.0	53.7	30.7	74.9	69.9	50.1

Table 3.4-22 Continued

	East Aspect			West Aspect		
	Fall 83	Spring 84	Fall 84	Fall 83	Spring 84	Fall 84
ARTR	2.6	2.9	1.5	5.9	2.0	0.7
ARCA	1.0	1.0	0.4	0.5	0.4	0.2
ATCO	0.2		0.1	0.1	0.1	0.2
CHGR	0.4	0.2	0.2	0.5	0.2	0.3
Total Shrubs	4.2	4.1	2.2	7.0	2.4	1.4
AGCR						1.1
AGSM	3.1	4.9	5.9	2.8	4.9	3.2
ORHY	0.5	1.7	0.8	0.2	2.7	0.4
UNK	1.6	--	--	1.6	--	--
Total Grasses	5.2	6.6	6.7	4.6	7.6	3.6
Seeding Success	Excel	Excel	Excel	Excel	Excel	Good
Cover						
Total	--	12.8	25.0	7.5	8.9	23.6
% Perennial	--	1.9	5.2	--	2.2	3.6
Total Bareground	--	59.0	47.9	57.8	49.7	27.5

changes in aspect and soil material (cut slopes, fill slopes, or borrow area) is shown in Table 3.4-22. Plant density averaged 6.4/m^2 on cut slopes, 9.9/m^2 on fill slopes, and 14.2/m^2 in borrow areas in June of 1984. By October of 1984 plant density on cut slopes decreased to 1.7/m^2, to 5.5/m^2 on fill slopes, and 13.0/m^2 on borrow areas. East and west aspects showed a plant density of 11.5/m^2 and 9.6/m^2, respectively in June 1984, but both decreased in October to 9.0/m^2 and 5.4/m^2.

Individual species performance on each of the treatments varied somewhat between sites. Sagebrush was the most abundant on cut slopes showing an increase in density over time. All other species densities decreased on cut slopes. Western wheatgrass was the most commonly found species on fill slopes but like all other species has declined in abundance over time. On borrow areas western wheatgrass and Indian ricegrass increased in density while both sagebrush and fourwing saltbush have declined. Western wheatgrass was the most common species on site with an easterly aspect and over the two sample years continues to increase in density. It is also the most abundant on westerly aspects, but like the other species is declining in density with time.

Overall, western wheatgrass is the most abundant species (4.8 plants/m^2), sagebrush second (1.8 plants/m^2), Indian ricegrass third (1.3 plants/m^2), fourwing saltbush fourth (0.5 plants/m^2), followed by Green's rabbitbrush (0.2 plants/m^2) and shadscale (0.1 plants/m^2).

Transplanted shrubs were also used in the revegetation of the roadside and associated cuts. An initial survey of survival of transplants in June 1983 showed that 83% of the plants were alive at Site 2 (1983 Report). Sagebrush had

the best survival (96%) and rabbitbrush had the poorest (50%). A transect in the same area in October 1983 showed that significant losses had occurred. The survival of sagebrush had decreased to 36% while no living transplants of fourwing saltbush or shadscale were found.

By spring of 1984 it was not possible to distinguish transplanted shrubs from seeded shrubs without sacrificing the plant. Therefore, in June and October of 1984 shrub density was determined for sagebrush, fourwing saltbush, shadscale and rabbitbrush (Table 3.4-23) at site 2 in an area 5.5m x 59.5 m paralleling the road. The number of plants of sagebrush and fourwing saltbush increased by approximately 50% from June to October, 1984. Shadscale decreased from 3 plants to 0 and rabbitbrush remained the same (4 plants).

Figure 3.4-14 represents a comprehensive qualitative assessment of revegetation success along the main mine access road. All the areas adjacent to the road that were revegetated in the fall of 1982 were mapped, and based on estimated perennial cover values and presence/abundance of seeded species, assigned to one of four revegetation success categories: excellent, good, fair and poor. Quantitative data were not collected at each site but information obtained from the 12 revegetation monitoring sites was used in categorizing the revegetated areas. This map provides a visual documentation of disturbed areas that have been successfully revegetated and areas that may require additional revegetation effort.

In the fall of 1983 a large percentage of the disturbed areas near the plant site was revegetated. A combination of seeding and transplanting was used. Two seed mixes, one for permanent revegetation and one for temporary

Table 3.4-23 Shrub density at Site 2 along main access road to the plant site.

Species	No. Plants/Area (approx. 3.5m x 59.5m) June 84	Oct 84
ARTR	20	30
ATCA	22	35
ATCO	3	0
CHNA	4	4
Total	49	69

Table 3.4-24 Seed mixes used for the fall 1983 seeding and list of the transplants by species used in revegetation efforts.

Permanent Seed Mix (11.5 acres)

	PLS LBS.
Indian ricegrass (Oryzopsis hymenoides)	2.0
Western wheatgrass (Agropyron smithii)	2.0
Shadscale (Atriplex confertifolia)	1.0
Fourwing saltbush (Atriplex canescens)	1.6
Mat saltbush (Atriplex corrugata)	1.0
Castle valley clover (Atriplex cuneata)	0.7
Trident saltbush (Atriplex tridentata)	0.6
Winterfat (Ceratoides lanata)	0.6
Big sagebrush (Artemisia tridentata)	0.2
Rubber rabbitbrush (Chrysthamnus nauseousus)	0.1

Temporary Seed Mix (topsoil stockpiles, 3.5 acres)

	PLS LBS.
Western wheatgrass (Agropyron smithii)	9.3
Russian wildrye (Elymus junceus)	7.3
Indian ricegrass (Oryzopsis hymenoides)	2.4
Scarlet globemallow (Sphaeralcea coccinea)	1.4
Rocky Mtn. penstemon (Penstemon strictus)	1.1
Rubber rabbtibrush (Chrysothamnus nauseosus)	0.1

Approximate number of transplants planted in the fall of 1983.

Summer cypress	(Kochia prostrata)	1000
Gardner saltbush	(Atriplex gardneri)	2000
Fourwing saltbush	(Atriplex canescens)	3000
Big sagebrush	(Artemisia tridentata)	3000
Black sagebrush	(Artemisia nova)	2000
Rubber rabbitbrush	(Chrysothamnus nauseosus)	3000

revegetation were used (Table 3.4-24). The reseeded areas are marked on Figure 3.4-15. Sampling was accomplished with techniques used on the 1982 seeded areas. Plant (seedling) densities were taken at some sites in June 1984 and all sites were sampled in October of 1984. The results of the first year's sampling efforts are reported in Table 3.4-25 for the June sampling and Table 3.4-26 for the fall sampling. Density values correspond to Figure 3.4-15 Maps A-C.

In the spring of 1984, 8 revegetation monitoring plots located in areas seeded in the fall of 1983 were sampled. The average plant density for all 8 plots was 18.2 plants/m^2. Of the 18.2 plants/m^2, 11.2 were grasses and 7.0 were shrubs. Three of the 8 plots sampled fell into the excellent revegetation success category, 2 in the good, one in the fair and two in the poor. The species most commonly encountered were sagebrush (2.9 plants/m^2), followed by fourwing saltbush (1.7 plants/m^2) and shadscale (1.4 plants/m^2). There were 10.4 grass seedlings/m^2 but due to their immaturity it was impossible to distinguish between species.

A total of 17 sites located in areas seeded in 1983 were sampled in October of 1984 (Table 3.4-26). The average plant density for all plots was 29.4 plants/m^2. Based on Vallentines revegetation success criteria 9 sites would fall into the excellent category, 4 in the fair and 4 in the poor. Of the 29.4 plants/m^2, 18.6 were grasses, 6.3 shrubs and 4.5 forbs. The species encountered most commonly was western wheatgrass (9.6 plants/m^2), next most common was Indian ricegrass (8.8 plants/m^2, and the most common shrubs were sagebrush (1.8 plants/m^2), and cuneate saltbush (1.3 plants/m^2).

Several areas that were reseeded in the fall of 1983 also were revegetated

Table 3.4-25 Plant density by species at eight revegetation monitoring plots, June 1984. (See figure 3.4-15 A-C for corresponding site locations.)

	Water Well Access Road			Mine Access Road			Retention Dam Area	
	1-A June	2-A June	4-A June	9-B June	16T-B June	16S-B June	1a-C June	8n-C June
Species								
Shrubs:								
ARTR	17.0	4.5	2.0					
ATCA	8.0	1.0		1.0	.5		1.5	1.5
ATCO	7.5	2.5					1.0	
ATCOR		3.5						
ATCU								
CELA								
CHNA	1.5	.5	1.5					
ATSPP			.5					1.0
Grasses	62.0	8.0		5.0			10.0	.5
AGSM								
ORHY			4.0					
ELJU								
Forbs	.5	.5	.5	1.0			.5	.5
Non-Seeded	44.5	113.0	54.5	26.0	81.0	20.5	16.0	23.5
Total Seeded	96.0	20.0	6.0	6.0	.5	0	12.5	3.0
Seeding Success	E	E	G	G	P	P	E	F

Table 3.4-26 Plant density by species at 17 revegetation monitoring plots, October 1984. (See figure 3.4-15 A-C for corresponding site locations.)

	Water Well Access Road						Mine Access Road				Retention Dam Area						
	1-A Oct	2-A Oct	3-A Oct	4-A Oct	5-A Oct	6/7-A Oct	8-B Oct	9-B Oct	16T-B Oct	16S-B Oct	1a-C Oct	1b-C Oct	2-C Oct	3,4,5-C Oct	6-C Oct	8s-C Oct	8n-C Oct
Species																	
Shrubs:																	
ARTR	6.0	7.0		3.0			.5	.5				10.4	1.0	1.0	.5	1.0	.5
ATCA	1.0	1.0						.5	.5		.8	4.0	.5	.5		1.0	1.0
ATCO	2.5	2.0					.5	1.5			1.6	4.8	1.5			2.0	1.5
ATCOR	1.0	1.0						.5			1.6	2.4	.5	.5		.5	2.0
ATCU	2.0	2.0									4.8	9.6	1.0	.5		.5	2.5
CELA	.5										2.4	5.6				.5	
CHNA	.5	.5												.5			
ATSPP.		.5						.5				.8				1.5	1.5
Grass				1.0													
AGSM	9.5	3.5	1.5	2.0	1.8	1.5	65.0	18.0	3.5		16.0	19.2		14.5	1.0	3.5	3.0
ORHY	12.5	5.0	0.4	0.5		2.0	6.0	6.0	.5		73.6	18.4		16.5	.5	2.5	5.0
ELJU					.4	1.5		1.0			.8						
Forbs	1.0	1.0		1.5	.9		66.0	3.5			.8		2.0		.5		
Non-Seeded	7.5	15.0	74.0	25.0	43.6	16.20	93.5	10.5	17.6	8.8	1.6			23.5	53.5	10.0	5.5
Total Seeded	35.5	22.5	1.9	3.5	2.2	5.0	72.0	28.5	4.5	0	101.6	75.2	4.5	34.0	2.0	13.0	17.0
Seeding Success	E	E	P	F	P	F	E	E	F	P	E	E	F	E	P	E	E

Table 3.4-27 Summary of plant density by species on areas seeded in the fall of 1983. (See Figure 3.4-15 for locations.)

Species	Spring 1984 8 plots sampled	Fall 1984 17 plots sampled
Shrubs:		
ARTR	2.9	1.8
ATCA	1.7	.6
ATCO	1.4	1.1
ATCOR	.4	.6
ATCU	.0	1.3
CELA	.0	.5
CHNA	.4	.1
ATSPP.	.2	.3
Grass	10.7	
AGSM	.0	9.6
ORHY	.5	8.8
ELJU	.0	.2
Forbs	.4	4.5
Non-Seeded	47.4	23.9
Total Seeded	18.2	29.4
Seeding Success	E	E

with transplants. Shortly after the transplants were in place 4 revegetation monitoring plots were selected to monitor transplant survival and growth. One was at site 1, one at site 2 and two at site 4 (Figure 3.4-15 Map A). Each plot was marked and the plants were mapped. Monitoring of plant survival and height was conducted in the spring of 1984 to assess winter damage and again in October to evaluate summer growth. A summary of the survival and growth of the transplants at all 4 plots is presented in Table 3.4-28 and a breakdown by plot is given in Table 3.4-29. A slight decrease in % survival occurred in the first year. The most significant is at site 4B where sagebrush survival dropped from 93% in June of 1984 to 79% in October. Overall sagebrush and summer cypress have the lowest percent survival (85% and 86%). Both shadscale and Gardner saltbush show 100% survival, fourwing saltbush 96% and rabbitbrush 94%. In general transplant survival on the four sites has been very good.

Table 3.4-28 Summary by species of survival of shrubs transplanted in the fall of 1983.

	% Survival		
	April 1984	June 1984	October 1984
ARTR	99.5	97	85
ATCA	96	96	96
ATCO	100	100	100
ATGA	100	100	100
CHNA	95	94	94
KOPR	100	86	86

Table 3.4-29 Survival of shrubs transplanted in fall of 1983 at sites along the water well access road. (See Figure 3.4-15 A for site locations.)

	April 1984	June 1984	October 1984
Site 1			
Totals:			
Avg. Ht.	15	18	34
% Survival	91	91	91
ARTR:			
Avg. Ht.	13	19	19
% Survival	100	91	91
ATCA:			
Avg. Ht.	19	19	43
%. Survival	90	90	90
ATGA:			
Avg. Ht.	5	4	31
% Survival	100	100	100
CHNA:			
Avg. Ht.	10	16	33
% survival	77	85	85
Site 2			
Totals:			
Avg. Ht.	17	14	30
% Survival	98	94	93
ARTR:			
Avg. Ht.	6	13	13
% Survival	100	100	88
ATCA:			
Avg. Ht.	18	15	40
% Survival	95	95	95
CHNA:			
Avg. Ht.	19	14	29
% Survival	100	95	95

Table 3.4-29 Continued

	April 1984	June 1984	October 1984
Site 4A			
Totals:			
Avg. Ht.	13	14	21
% Survival	98	95	93
ARTR:			
Avg. Ht.	10	12	13
% Survival	100	100	83
ATCA:			
Avg. Ht.	9	18	24
% Survival	100	100	100
ATCO:			
Avg. Ht.	6	11	11
% Survival	100	100	100
ATGA:			
Avg. Ht.	6	20	24
% Survival	100	100	100
CHNA:			
Avg. Ht.	16	14	23
% Survival	100	96	96
Site 4B			
Totals:			
Avg. Ht.	12	18	21
% Survival	96	93	79
ARTR:			
Avg. Ht.	13	18	19
% Survival	98	96	78
ATCA:			
Avg. Ht.	11	8	18
% Survival	100	100	100

Table 3.4-29 Continued

	April 1984	June 1984	October 1984
ATGA:			
Avg. Ht.	3	4	21
% Survival	100	100	100
KOPR:			
Avg. Ht.	7	18	33
% Survival	100	86	86

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4.0 AQUATIC BIOLOGY

4.0 AQUATIC BIOLOGY

4.1 INTRODUCTION

The 1984 aquatic biology monitoring program was conducted under the direction of Ecosystem Research Institute, Inc. of Logan, Utah.

During 1984, data was collected at two selected cross-stream monitoring transects which are located upstream and immediately downstream of Tracts Ua and Ub. Data collected included physical, chemical and biological parameters of the aquatic system. Data collection followed the program outlined in the Environmental Monitoring Manual (EMM) published by WRSOC in 1982 and revised in 1983 (WRSOC 1982). Methodology, QA & QC procedures are outlined in these reports.

4.2 PROGRAM SUMMARY

The 1984 aquatic biology monitoring program continued to document the physical, chemical and biological dynamics of the White River near Tracts Ua and Ub.

During 1984 as in 1982 and 1983, the White River system was characterized by elevated flows and increased suspended solids (TSS). Discharge levels and TSS were higher during 1984 than in three previous years. River habitats were greatly changed in some instances due to the high flows. Water chemistry parameters, particularly nutrients in the forms

of nitrogen and phosphorus followed similar patterns with river discharge as in previous years. During 1984, however, levels were elevated in comparison to previous years.

The biology of the system continued to respond to physical influences. The high scouring action and reduced light penetration of increased sediment loads regulated algal production during 1984 as in previous years. 1984 data furnished further evidence that the White River is a light- and substrate-limited system in which primary production is limited during much of the year even though sufficient nutrients may be present.

Due to high discharge levels and difficult sampling conditions during 1984, insufficient samples were collected to allow accurate determination of production patterns from month to month. On a gross level however, the macroinvertebrate community appeared to respond to scouring effects of ice and discharge. During high flow periods and following periods when icy conditions prevailed, numbers and biomass were depressed. 1984 macroinvertebrate production at Transect WR03 was similar to that in 1983. Transect WR18 numbers and biomass were depressed in comparison to levels measured during 1983.

Comparisons of biological parameters for control and treatment sites showed that chlorophyll a, macroinvertebrate numbers and biomass were not significantly different between transects WR03 and WR18. These analyses showed that WR03 (control) and WR18 (treatment) sites were responding similarly.

4.3 PROGRAM DESCRIPTION

This section discusses aquatic biology program objectives and provides a summary of important 1984 program features including the quality control program.

4.3.1 1984 Monitoring Program

The Environmental Monitoring Manual (WRSOC 1982) established the aquatic biology monitoring program in its initial form. Long-term sample sites were delineated at six transect locations in the White River. These were riffle transects WR03, WR18, WR27 and pool transects WR05, WR20 and WR29. These sites were selected from twenty-nine transects surveyed in the White River and nine in Evacuation Creek during an initial stream survey in 1981. See Figure 4.3-1 for transect locations.

At the end of 1982, sampling was discontinued on the pool transects due to high variability in biological parameters when compared to riffles. During 1983, all efforts were focused on the three riffle transects. The downstream transect, WR27, changed in character from a riffle to a pool or run-type habitat. This destroyed the comparability of the location with the upstream riffle transects. Sampling at transect WR27 was discontinued after August, 1983. During 1984, monitoring efforts focused on upstream transect WR03 and transect WR18 immediately downstream of Southam Canyon.

The EMM delineated three levels of monitoring parameters: operational, potential and contingency. These categories were created to provide flexibility in program design. As parameters are adequately categorized or determined to be of low value for monitoring they may be moved from operational to contingency categories. Those potential or contingency

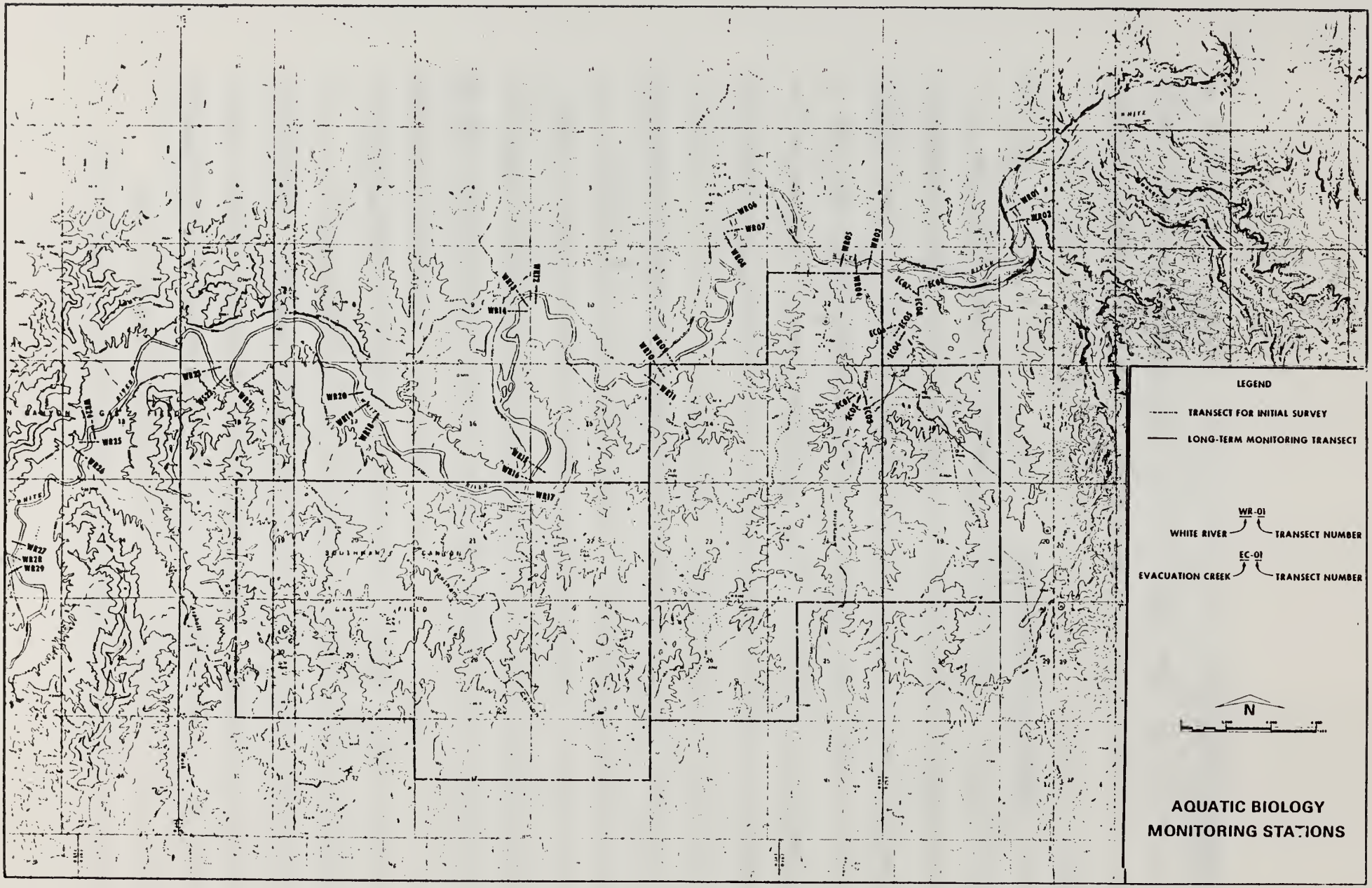


Figure 4.3-1. Location of aquatic biology transects in the White River and Evacuation Creek. WR03 and WR18 were monitoring sites used during 1984.

parameters determined useful for monitoring may become operational.

Two sets of parameters were changed in status during 1983. Periphyton taxonomic characteristics including species richness, species biomass, community biomass, density and diversity were moved from operational to contingency status. In addition, measurement of drifting insects was moved from the potential to the contingency category. During 1984, monitoring efforts focused on operational parameters presented in this report.

The long-term program described in the EMM had three major objectives:

- To gather data which describes the aquatic ecosystem in sufficient detail to allow assessment of natural or project-related change.
- To organize data collection and analysis using a conceptual view of the ecosystem to determine the cause or pathway of these changes.
- To assess the effectiveness of mitigation or reclamation measures.

During 1983, in addition to routine collection of monitoring data further experiments were conducted to reduce sampling variability. This effort involved the use of substrate baskets containing cobble-sized substrate at locations on WR03 and WR18. The goal of this experiment was to determine if variability at a single location could be reduced by introduction of replicate uniform substrates and to determine if data collected at two different transects were comparable using these introduced substrates. The results of this experiment are discussed in Section 4.4.

During 1984, sampling locations within each transect were chosen using a random numbers table. This was done to meet the required assumptions of an analysis of variance to test for differences between transects.

4.3.2 Quality Control Program (QA/AC)

Three aspects of the aquatic biology quality control program for 1984 are discussed in this section. These are (1) water quality, (2) biological and (3) equipment calibration.

4.3.2.1 Water Quality. The water quality QA/QC program has been in operation for two years. Utah State Department of Health and EPA certification requirements for a variety of water QA/QC parameters have been fulfilled for a second year. The water quality control program consists of two analytical elements; daily precision and accuracy checks and quarterly audit samples.

A. Precision and Accuracy Each time water quality samples are analyzed, ten percent are subjected to tests of precision and accuracy in accordance with EPA procedures for quality control. Percent deviation from the average and percent relative error from daily precision and accuracy, respectively, are compared with compiled data from previous years. Daily precision and accuracy values must fall within ± 2 relative standard deviations of this compiled data.

At the start of 1984, ERI had one year of daily precision and accuracy data that were collected when the lab was under certification. These were used to generate acceptable ranges for daily precision and accuracy for comparison with values calculated in 1984. In all cases, these acceptable ranges were narrower than those generated from EPA audit samples as used in the 1983 ERI quality control program. It was decided to use the ERI levels as a goal, but to redo the analyses when they fell outside the levels used in 1983.

Daily precision and accuracy were performed on all water quality parameters measured for WRSP except pH. These consist of nitrate, nitrite, ammonia, orthophosphate, total dissolved phosphorus, total phosphorus, total dissolved solids, total suspended solids and specific conductance. Data for a single parameter, nitrate, is shown in Table 4.3-1. Tables for all parameters are available but were considered too lengthy for inclusion within this report.

A brief summary of the daily precision and accuracy for all quality control samples during 1984 for these parameters are shown in Table 4.3-2. The acceptable ranges based on 1983 data for percent deviation from the average (precision) and percent relative error (accuracy) are shown along with the number of quality control samples and the number of samples that were outside these ranges. None of the samples that fell outside the ranges based on the 1983 data fell outside of the EPA-based levels used in 1983.

B. Quarterly Audit Quarterly audit samples obtained from EPA continued to be used for quality control during 1984. Results of analyses for first quarter WRSP parameters are shown in Table 4.3-3. Results for all quarters are available but too lengthy for inclusion in this report. All audit sample analyses fell within acceptable guidelines.

4.3.2.2 Invertebrate Sample Processing. Quality control procedures were again employed on invertebrate sample processing. As before, selected samples were reprocessed (hand-picking of invertebrates from debris and algae present in sample) to determine the recovery level of invertebrates. Goals of recovering 85% of the individuals and 95% of the invertebrate biomass were set as acceptable levels for the sample processing.

Table 4.3-1. Daily quality control results for nitrate analyses during 1984.

			PRECISION			ACCURACY				
Date	Log #	Lev	Mean	% Dev	Range	Th-Sp	Ex-Sp	% Rec	Rel Err	Range
840307	123-4994W	I	99.5	1.51	[-14.40, 14.40]	117.16	123.93	105.78	5.78	[-21.50, 33.30]
840418	149-5119W	I	90.0	-1.11	[-14.40, 14.40]	107.84	109.65	101.68	1.68	[-21.50, 33.30]
840425	196-5224W	I	53.5	2.80	[-14.40, 14.40]	72.06	76.50	106.16	6.16	[-21.50, 33.30]
840428	196-5236W	I	60.5	0.83	[-14.40, 14.40]	78.92	80.58	102.10	2.10	[-21.50, 33.30]
840423	154-5177W	I	55.5	2.70	[-14.40, 14.40]	74.02	78.54	106.11	6.11	[-21.50, 33.30]
840423	164-5187W	I	62.5	0.80	[-14.40, 14.40]	80.88	84.66	104.67	4.67	[-21.50, 33.30]
840521	218-5446W	I	60.0	-1.67	[-14.40, 14.40]	78.43	81.09	103.39	3.39	[-21.50, 33.30]
840521	228-5456W	I	75.0	5.33	[-14.40, 14.40]	93.14	103.53	111.16	11.16	[-21.50, 33.30]
840521	238-5466W	I	102.0	0.98	[-14.40, 14.40]	109.80	111.69	101.72	1.72	[-21.50, 33.30]
840705	250-5540W	I	55.0	7.27	[-14.40, 14.40]	73.53	82.11	111.67	11.67	[-21.50, 33.30]
840906	275-5730W	I	97.5	0.51	[-14.40, 14.40]	115.20	121.38	105.37	5.37	[-21.50, 33.30]
841014	287-5920W	I	142.5	3.16	[-14.40, 14.40]					
841108	310-6057W	I	82.0	-2.44	[-14.40, 14.40]	100.00	105.06	105.06	5.06	[-21.50, 33.30]
840308	126-5016W	L	43.0	0.00	[-14.40, 14.40]	61.76	65.79	106.52	6.52	[-21.50, 33.30]
840116	097-4921W	L	45.5	1.10	[-14.40, 14.40]	64.22	65.79	102.45	2.45	[-21.50, 33.30]
840316	130-5039W	L	15.5	-9.68	[-14.40, 14.40]	34.80	34.68	99.64	-0.36	[-21.50, 33.30]
840424	152-5168W	L	8.0	0.00	[-14.40, 14.40]	27.45	28.05	102.18	2.18	[-21.50, 33.30]
840417	179-5202W	L	34.0	0.00	[-14.40, 14.40]	52.94	56.61	106.93	6.93	[-21.50, 33.30]
840523	245-5483W	L	13.5	-3.70	[-14.40, 14.40]	32.84	36.21	110.25	10.25	[-21.50, 33.30]
840622	247-5491W	L	20.0	0.00	[-14.40, 14.40]	39.22	40.29	102.74	2.74	[-21.50, 33.30]
840731	260-5604W	L	50.5	2.97	[-14.40, 14.40]	69.12	72.93	105.52	5.52	[-21.50, 33.30]
840806	263-5636W	L	8.0	0.00	[-14.40, 14.40]	27.45	28.05	102.18	2.18	[-21.50, 33.30]
840826	272-5672W	L	13.5	3.70	[-14.40, 14.40]	32.84	36.21	110.25	10.25	[-21.50, 33.30]
840828	273-5685W	L	14.5	3.45	[-14.40, 14.40]	33.82	37.23	110.07	10.07	[-21.50, 33.30]
840925	280-5780W	L	7.0	0.00	[-14.40, 14.40]	26.47	28.05	105.97	5.97	[-21.50, 33.30]
840923	279-5775W	L	48.5	1.03	[-14.40, 14.40]	67.16	72.42	107.84	7.84	[-21.50, 33.30]
841003	284-5860W	L	40.5	1.23	[-14.40, 14.40]	59.31	59.67	100.60	0.60	[-21.50, 33.30]
841124	314-6128W	L	8.0	0.00	[-14.40, 14.40]	27.45	27.03	98.47	-1.53	[-21.50, 33.30]

(1) Percent deviation from average $= \left(\frac{x_i - \bar{x}}{\bar{x}}\right) \times 100$

(2) Percent recovery $= \left(\frac{\text{experimental spike}}{\text{theoretical spike}}\right) \times 100$

(3) Percent relative error $= \left(\frac{\text{experimental spike} - \text{theoretical spike}}{\text{theoretical spike}}\right) \times 100$

Table 4.3-2. Daily precision and accuracy for water quality parameters measured for WRSOC during 1984. Acceptable range is in percent.

	Precision			Accuracy		
Analysis	Acceptable Range	Number Samples	Number Outside Range	Acceptable Range	Number Samples	Number Outside Range
Nitrate	-14.4 to 14.4	28	0	-21.5 to 33.3	27	0
Nitrite	-3.8 to 3.8	27	3	-13.8 to 13.8	27	0
Ammonia	-26.2 to 26.2	25	4	-12.1 to 18.9	25	1
Total Phosphorus	-13.6 to 13.6	42	1	-17.7 to 24.3	41	0
Total Dissolved Phosphorus	-12.0 to 12.0	8	1	-12.6 to 12.6	8	0
Orthophosphate	-4.4 to 4.4	30	1	-2.7 to 11.1	30	1
Total Suspended Solids	-11.4 to 11.4	31	4	--	-	-
Total Dissolved Solids	-3.8 to 3.8	17	0	-4.2 to 4.2	17	0
Specific Conductance	-1.6 to 1.6	19	1	-4.5 to 8.7	19	1

Table 4.3-3. First quarter results of EPA audit samples for 1984.

Parameter	ERI Value	EPA Value	$\bar{x}$	S	95% CI
Specific Conductance (umhos/cm)	568	568	564	30	504-624
	204	216		6	204-227
pH (units)	5.60	5.7	5.7	.06	5.58-5.82
	7.73	7.8	7.8	.08	7.64-7.89
Ammonia (mg/l)	.147	.14		.025	.09-.19
	.995	.95		.11	.73-1.17
Nitrate (mg/l)	.826	.715		.065	.585-.845
	.083	.07		.015	.04-.10
Orthophosphate (mg/l)	.023	.025		.01	.005-.045
	.170	.175		.01	.155-.195
Total Phosphorus (mg/l)	1.068	1.04	1.06	.06	.94-1.18
	.136	.14	.15	.05	.05-.25
Total Suspended Solids (mg/l)	32.4	35.0	30.3	2.15	26.0-34.6
	104	120	113	6.3	100-126
	518	550	532	27	477-586
Total Dissolved Solids (mg/l)	434	450	452	28	395-509
	267	300	304	22	259-348
	142	150	156	16	123-188

During 1984, 23 samples were repicked to determine the percent recovery for invertebrate processing. A list of these samples and the percent of the total individuals counted and total biomass recovered in the initial processing appears in Table 4.3-4.

For the 23 samples, a mean of 83.4% of the individuals and 90.6% of the biomass per sample were recovered. This represents an increase in recovery over the levels in 1982 and 1983.

A weighted mean was also calculated taking into account the total number of individuals and the total biomass of invertebrates present in the sample. This analysis showed that 86.4 and 97.2% of the individuals and biomass, respectively, were recovered across all samples. This falls within the levels set as acceptable at the outset of the year. The higher levels using the weighted means strongly suggests that the smaller samples are more subject to lower recovery levels. This is likely as a single missed individual would have more impact on the total numbers and biomass when the number of individuals in the sample is low.

4.4 PROGRAM RESULTS AND ANALYSIS

This section will discuss the results of physical, chemical and biological data collection in the aquatic biology monitoring program during 1984. These results will be compared to previous years. The results of special studies to document the relative variability between sampling across transects and introduced substrates for macroinvertebrates will be presented.

Table 4.3-4. Results of 1984 quality control for invertebrate sample processing.

Date	Transect	Log Number	Total Number	Number % Counted	Total Biomass(mg)	Biomass % Counted
840417	WR18	150-5144B	16	87.5	20.71	98.2
840419	WR03	149-5139B	22	68.2	4.56	88.9
840417	WR18	150-5145B	7	85.7	2.41	88.8
840419	WR03	149-5136B	62	82.3	41.86	98.2
840418	WR24	151-5149B	34	76.5	6.78	94.7
840419	WR03	149-5140B	30	90.0	18.08	98.9
840418	WR24	151-5150B	20	100.0	74.82	100.0
840418	WR24	151-5146B	7	85.7	1.10	95.6
840419	WR03	149-5137B	32	62.5	15.25	87.4
840417	WR18	150-5142B	48	85.4	20.29	98.3
840417	WR18	150-5141B	93	89.2	38.44	98.6
840417	WR18	150-5143B	46	78.3	19.54	96.5
840419	WR03	149-5138B	52	94.2	21.31	98.9
840418	WR24	151-5147B	5	100.0	3.29	100.0
840418	WR24	151-5148B	36	88.9	10.63	98.9
840515	WR03	216-5425B	16	50.0	57.77	98.6
840515	WR03	216-5427B	14	71.4	1.91	73.6
840515	WR03	216-5429B	47	91.5	34.31	55.1
840515	WR03	216-5428B	36	83.3	41.71	97.9
840515	WR03	216-5426B	15	66.7	6.48	21.0
840731	WR18	262-5629B	40	92.5	563.30	100.0
840731	WR03	260-5587B	121	96.7	64.50	99.1
840731	WR03	260-5585B	73	91.8	18.78	96.7
mean			379	83.4	47.30	90.6
weighted mean				86.4		97.2

4.4.1 The Physical Environment

During 1984, the White River experienced flows similar to 1983 and higher than in the previous two years of aquatic biology monitoring at tracts Ua and Ub. Increasing flows during 1981-1983 subjected the aquatic habitat to large geomorphic forces which resulted in gross changes to aquatic habitats. During 1984, with flow regimes similar to 1983, no major changes were noted in cross-stream transect profiles or physical habitat.

Cross-section profiles of the two riffle transects presently used in the aquatic biology monitoring program are presented in Figure 4.4-1. In this figure, profiles for August 1983 are presented along with pre- and post-runoff profiles for April and September, 1984 for comparison. It is evident from this figure and Table 4.4-1 that runoff events during 1984 did not create major changes in channel morphology, although WR18 is becoming less uniform in cross-section as the north side of the river channel is becoming deeper while a shallow shelf is developing on the south side.

Substrate composition data show that these two transects continue to be dominated by larger substrates. These substrates provide more stable habitat which allows for greater biological production (Table 4.4-2).

Interstitial sediment data for the current monitoring transects are shown in Figure 4.4-2. Transects WR03 and WR18 have maintained consistency through three years of data collection and are dominated by the larger size fractions. The rare exception to this has occurred twice on WR18 when ice dams slowed the current and allowed deposition of large quantities of fine sediments.

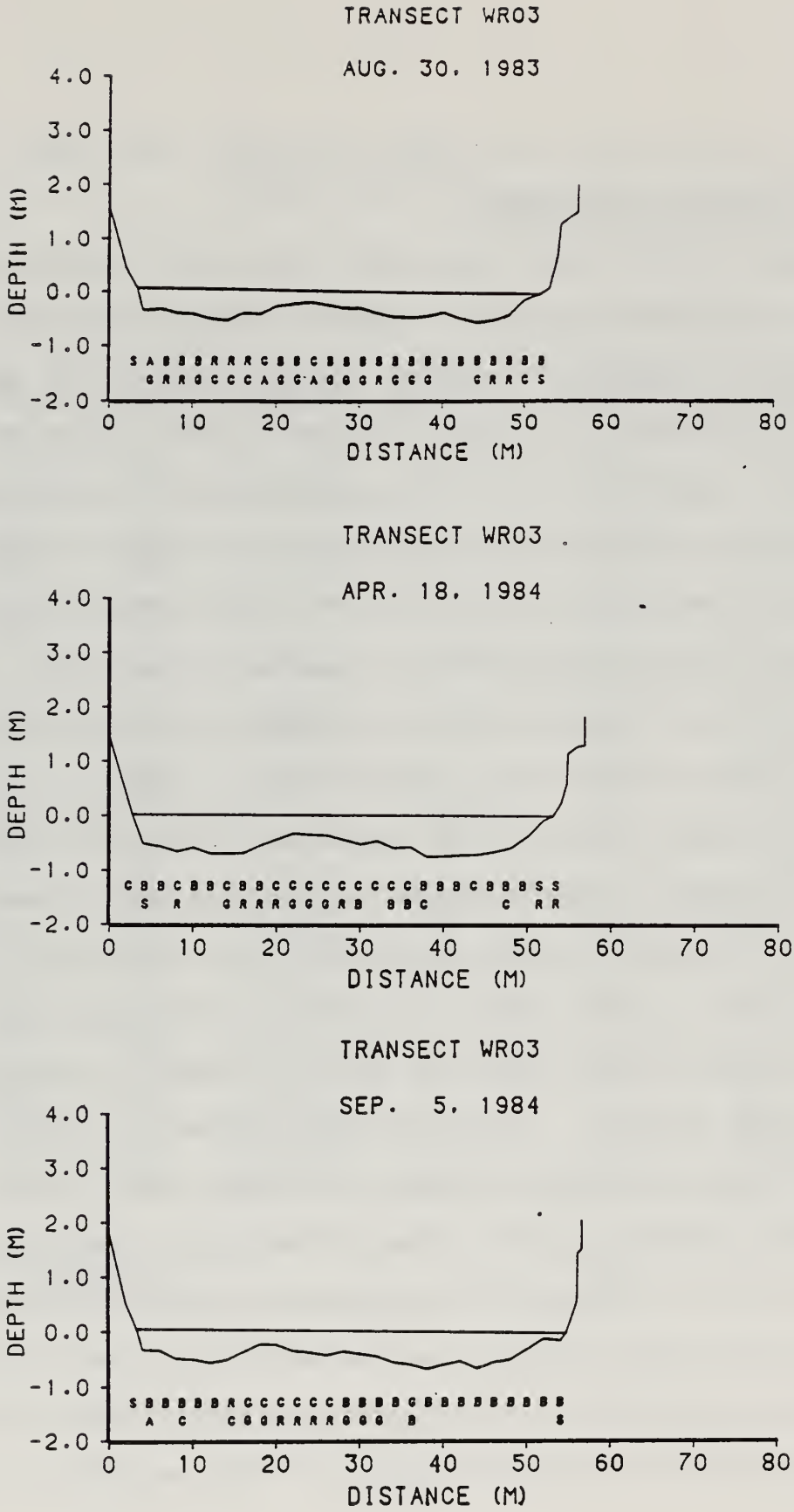


Figure 4.4-1a. Cross-section profiles of White River Transect WR03. August, 1983 is compared to April and September 1984.

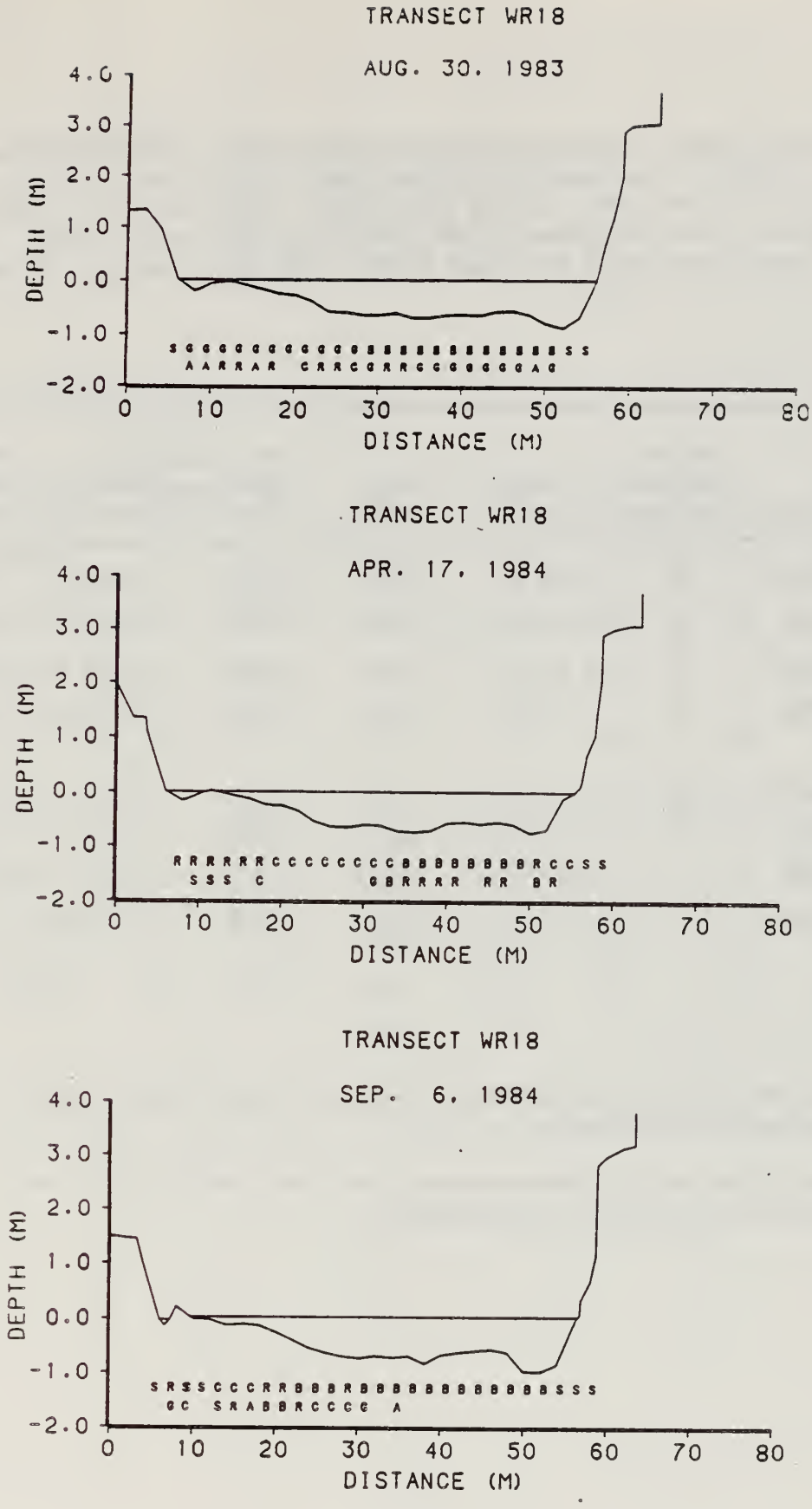


Figure 4.4-1b. Cross-section profiles of White River Transect WR18. August, 1983 is compared to April and September 1984.

Table 4.4-1. Mean width, depth and velocity characteristics of White River monitoring transects (riffles only) during 1981-1984. Means were calculated from the total of all data collected along each transect during each year (complete surveys only).

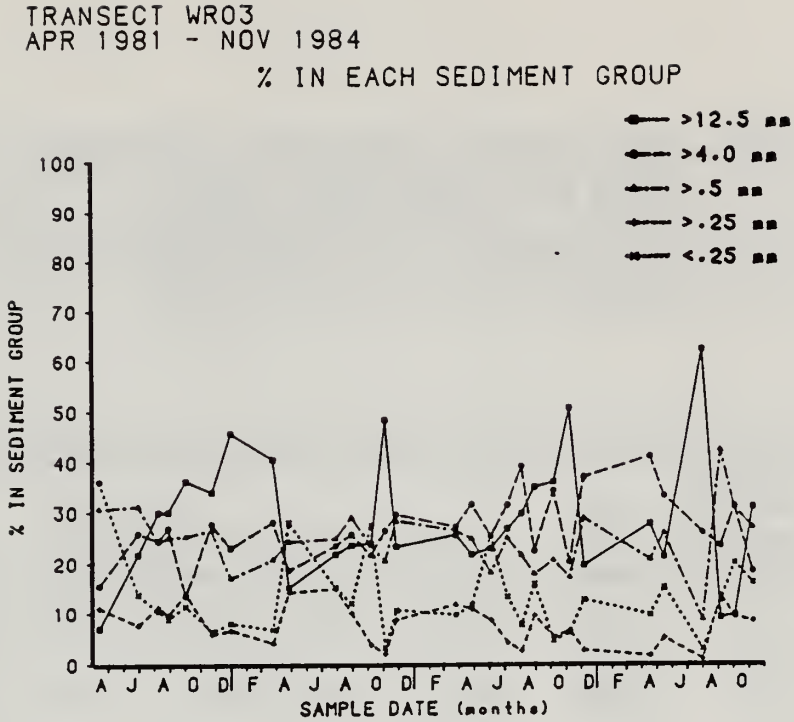
Location	Year	No. of Surveys Included	Width (m)	Depth (cm)	Max Depth (cm)	Velocity (cm/s)	Maximum Velocity (cm/s)
WR03	1981	8	38.5	25.1	55.8	57.5	109.0
	1982	6	45.9	32.1	68.2	63.6	122.7
	1983	5	49.5	49.4	77.6	53.1	109.2
	1984	4	50.5	44.0	70.3	82.6*	112.0*
WR18	1981	10	40.1	31.0	59.5	69.4	141.9
	1982	8	45.6	44.9	79.8	82.0	145.1
	1983	5	47.1	41.6	79.0	88.3	161.0
	1984	4	46.3	43.4	88.8	82.4**	148.7**

* Based upon two sets of measurements, one pre-runoff (April) and one post-runoff (September).

** Based upon three sets of measurements, one pre-runoff (April) and two post-runoff (September and November).

Table 4.4-2. Mean substrate composition (in percent) of White River monitoring transects (riffles only) during 1981-1984. Means were calculated from the total of all data collected along each transect during each year (complete surveys only).

Location	Year	No. of Surveys Included	BO	CO	RU	GR	SA	SI	CL
WR03	1981	6	38.2	29.8	7.0	0.7	4.6	16.1	3.6
	1982	6	40.2	25.2	13.7	10.2	4.8	6.0	0.0
	1983	5	32.2	21.1	14.6	21.7	3.1	7.3	0.0
	1984	4	58.2	16.9	8.9	4.0	1.8	9.3	0.9
WR18	1981	9	42.6	31.4	20.1	5.0	0.0	0.5	0.5
	1982	8	19.1	22.6	25.6	12.8	7.1	12.8	0.0
	1983	5	27.2	13.5	16.1	22.8	1.8	18.6	0.0
	1984	4	40.3	20.4	14.6	2.1	3.8	18.0	0.9



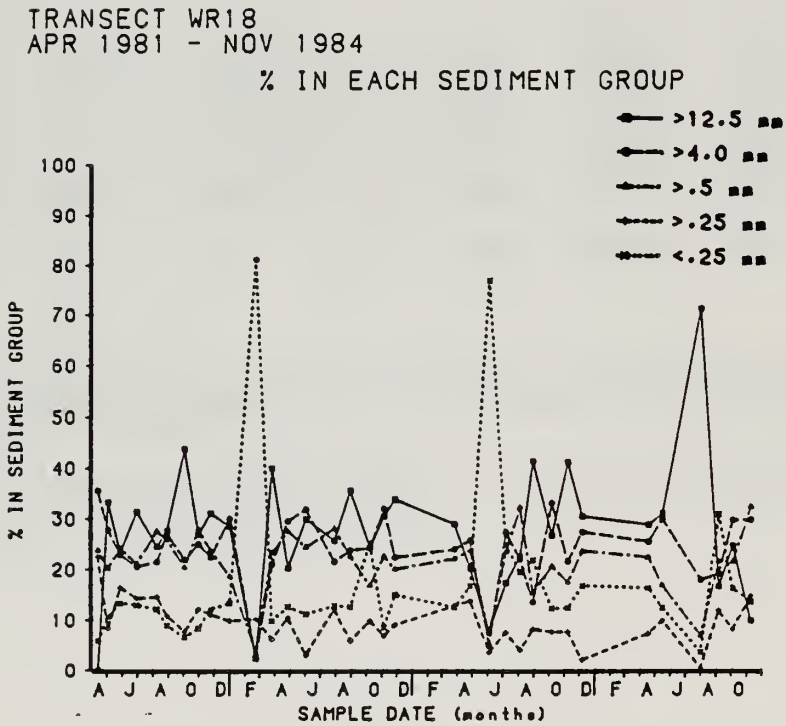


Figure 4.4-2. Interstitial sediment size fractions for White River Transects WR03 and WR18 from April, 1981 to November, 1984.

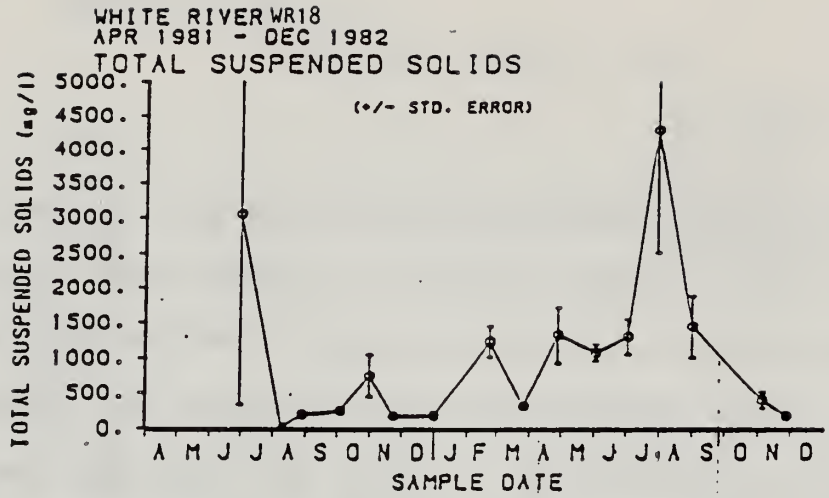
The pattern of total suspended solids concentration in 1984 followed a consistent trend with discharge events as in previous years (Figure 4.4-3). Maximum levels occurred in early June and were of similar magnitude as those attained during 1983. Suspended solids concentrations were similar at each transect during all sample periods. In 1984, replicate water samples were taken at all transects within the same day to reduce previously observed variability between transects. Comparing patterns and magnitudes of suspended solids observed at transects WR03 and WR18, it appears this source of variation was reduced.

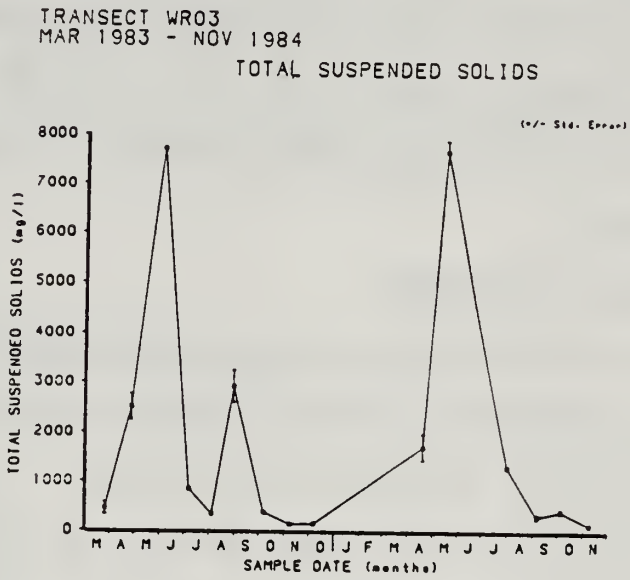
4.4.2 The Chemical Environment

During 1984, data continued to be collected on chemical parameters important to the biotic community. These included pH, conductivity and major forms of the nutrients, phosphorus and nitrogen.

Conductivity followed the same pattern observed in previous years (Figure 4.4-4). Values reached a peak of around 1000 umhos/cm during lower basin runoff in March-April in all years. As dilution took place during upper basin runoff in June, as dilution took place conductivity declined to low values of approximately 300 umhos/cm in all years. Water samples collected in 1984 were not taken during peak runoff. Following upper basin runoff, in summer and fall, values again increased to a level of around 700 umhos/cm. pH remained relatively constant at values around eight.

The patterns of nutrient concentrations measured at transect WR18 during 1981 and 1982 are shown in Figure 4.4-5. Total phosphorus and orthophosphate consistently followed a pattern of increased levels during high flows. Total inorganic nitrogen (TIN) followed a similar pattern.





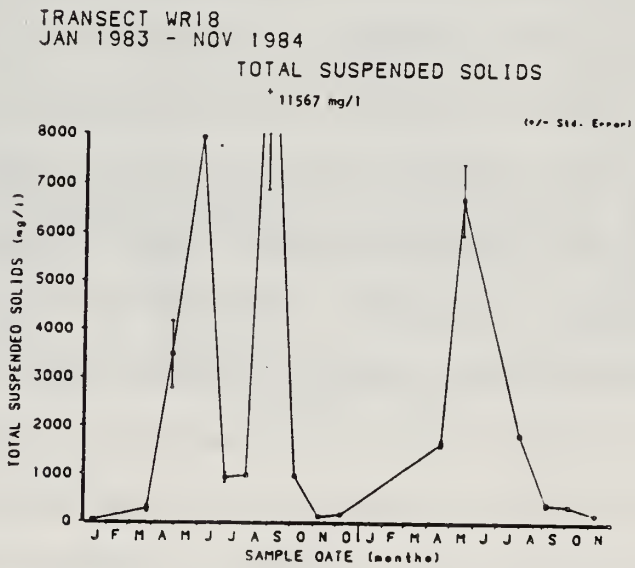


Figure 4.4-3. Total suspended solids data for White River Transects WR03 and WR18 from April, 1981 to November, 1984.

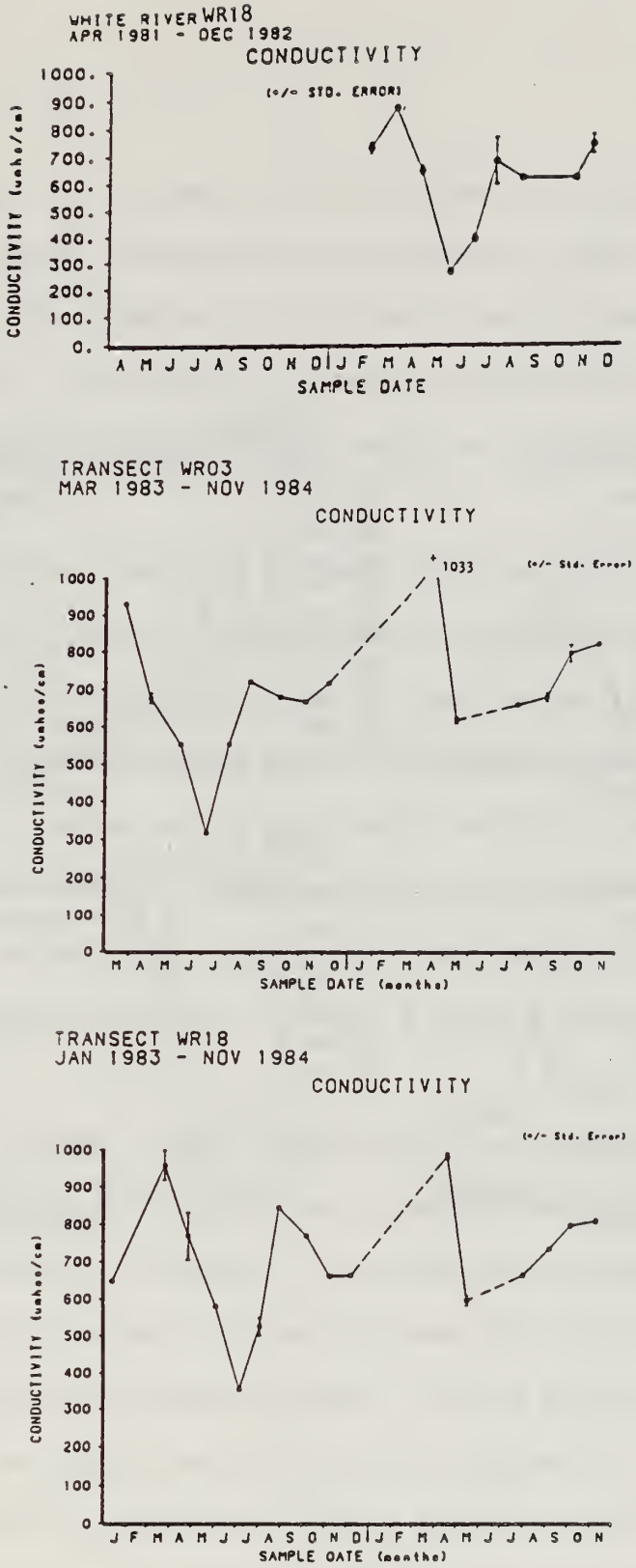


Figure 4.4-4. Conductivity in the White River at Transects WR03 and WR18 from January, 1982 to November, 1984.

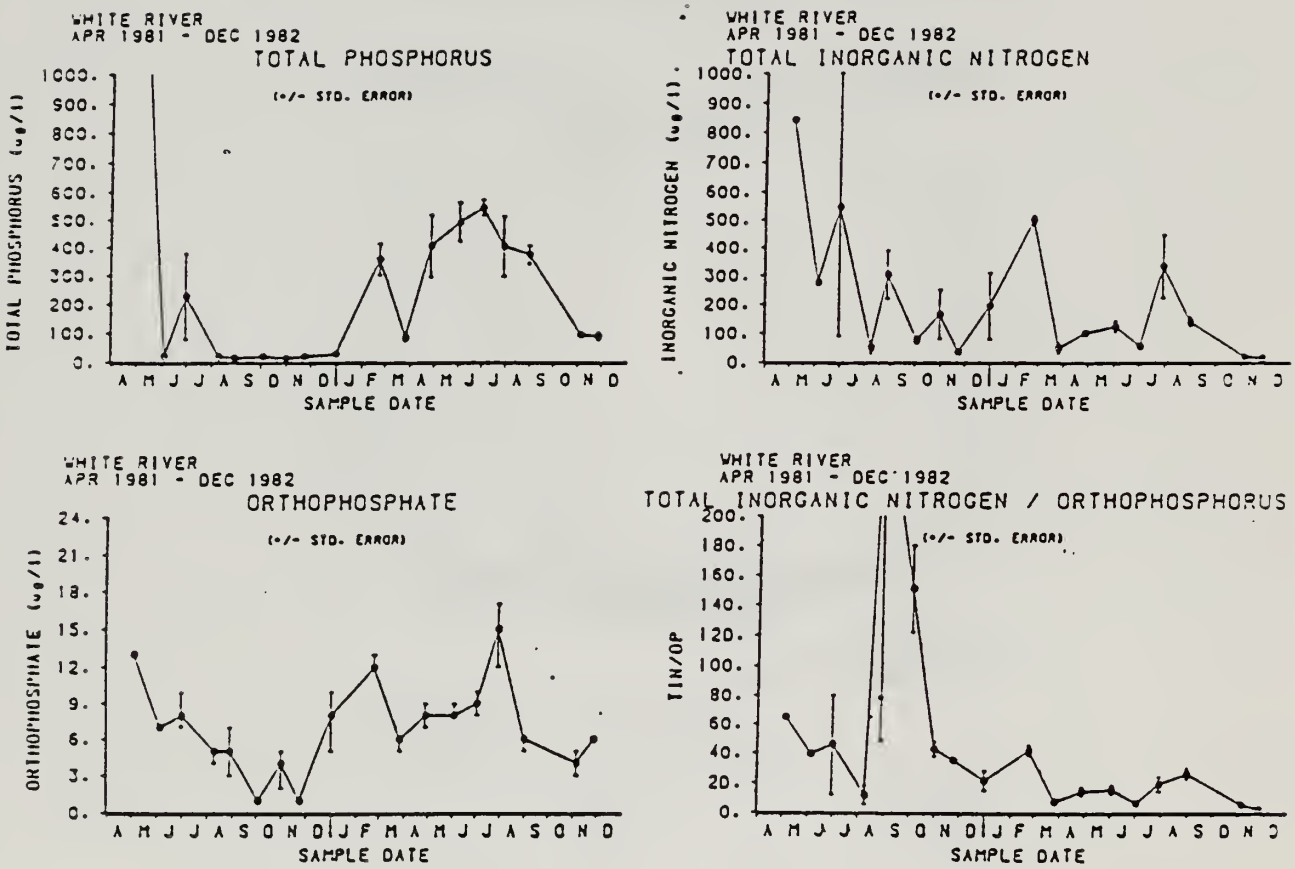
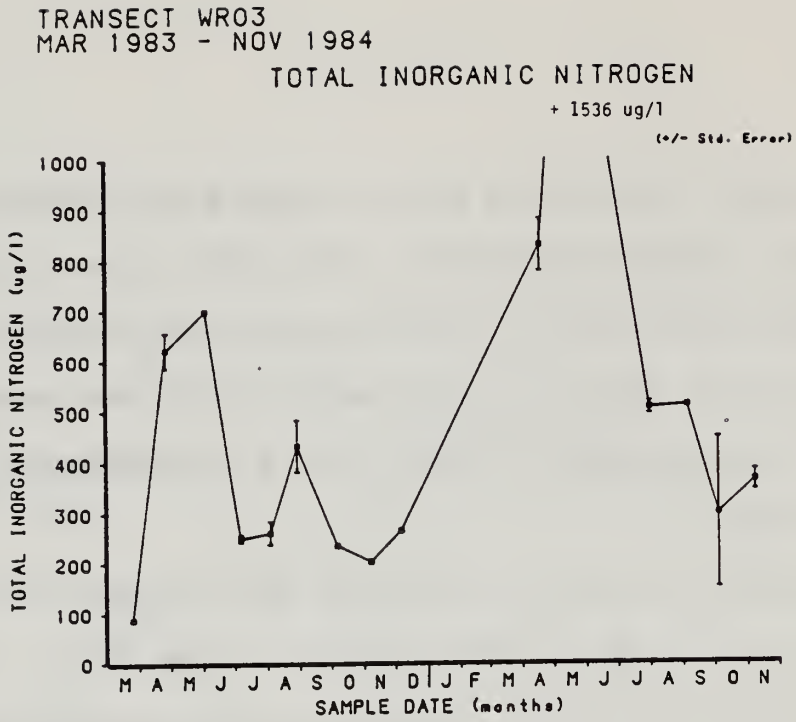


Figure 4.4-5. Total phosphorus, reactive phosphorus (orthophosphate), and total inorganic nitrogen (NH_3 + NO_3 + NO_2) in the White River at Transect WR18 during 1981 and 1982.

During 1984, TIN followed similar patterns with discharge as in previous years except concentrations were higher (Figure 4.4-6). TIN values reached approximately 1500 ug/l during May at each transect as compared to 700 in June, 1983. Values for the summer and fall were generally higher as well. As in previous years, nitrate (NO_2) and nitrite (NO_3) occurred at much lower levels.

Total phosphorus levels at transects WR03 and WR18 during 1983 and 1984 were higher than in 1981 or 1982 (Figures 4.4-5 and 4.4-7). This reflected particulate forms carried into the White River by overland flow during lower and upper basin runoff in these higher than normal flow years. Total phosphorus levels peaked during upper basin runoff in June of both years between 4000 and 6000 ug/l. Both monitoring transects followed the same trends in 1984, experiencing similar nutrient levels during each sample period. Orthophosphate levels reflected a similar pattern (Figures 4.4-5 and 4.4-8).

The ratio of total inorganic nitrogen to orthophosphate (TIN/OP) is used by limnologists to indicate when either of the major nutrients is in short supply relative to the other. When the ratio exceeds 15:1, the system is presumed to be phosphorus limited and when the ratio is less than 15:1, nitrogen limitation is presumed to occur. During 1983 and 1984, the (TIN/OP) ratio was always greater than 15:1 (Figures 4.4-5 and 4.4-9) indicating phosphorus limitation. Due to the high suspended solids load, consequent scouring and low light penetration, it is probable that during most of the year, insufficient light reaches the substrate to promote maximum algae growth with the nutrients present.



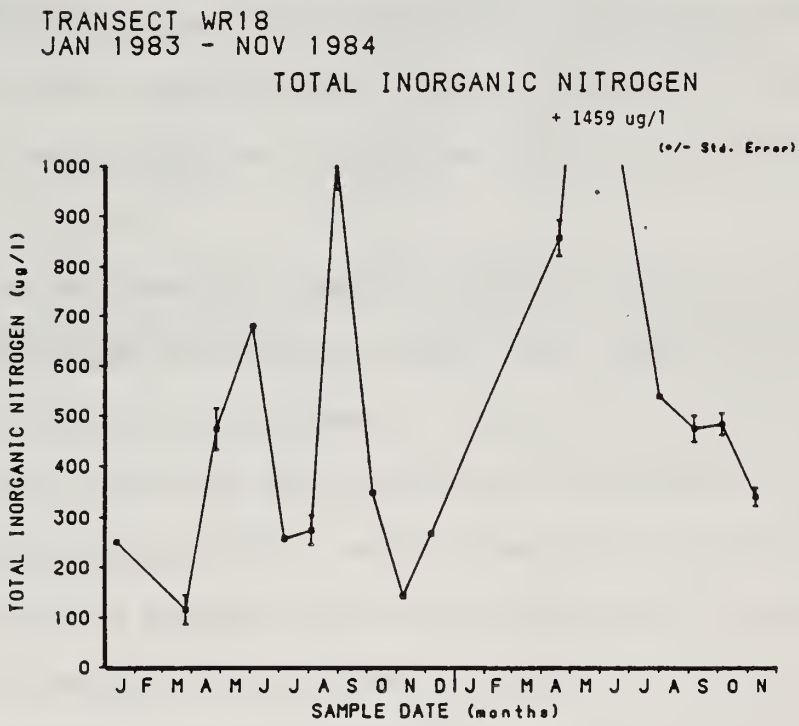
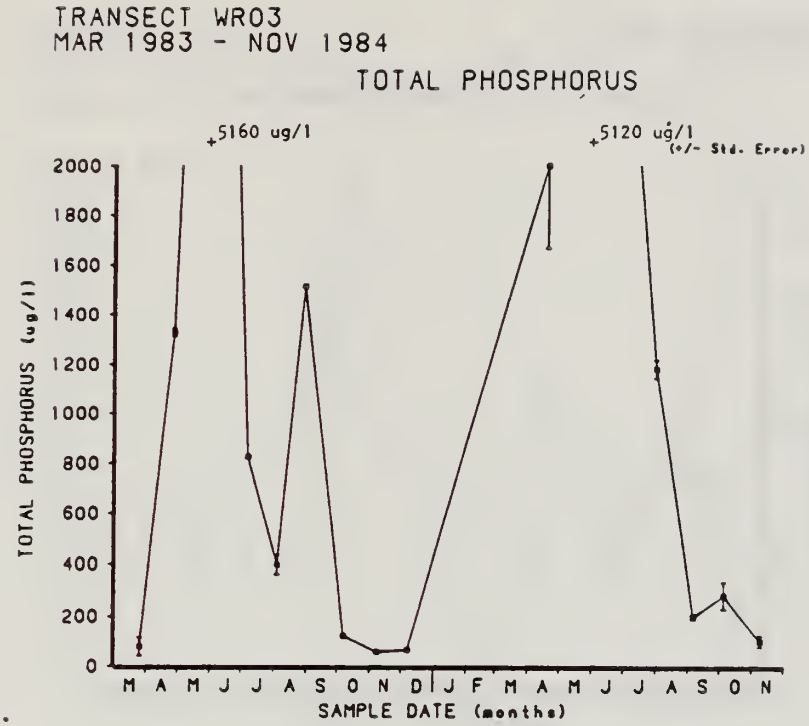


Figure 4.4-6. Concentration of total inorganic nitrogen (TIN) for White River Transects WR03 and WR18 during 1983 and 1984.



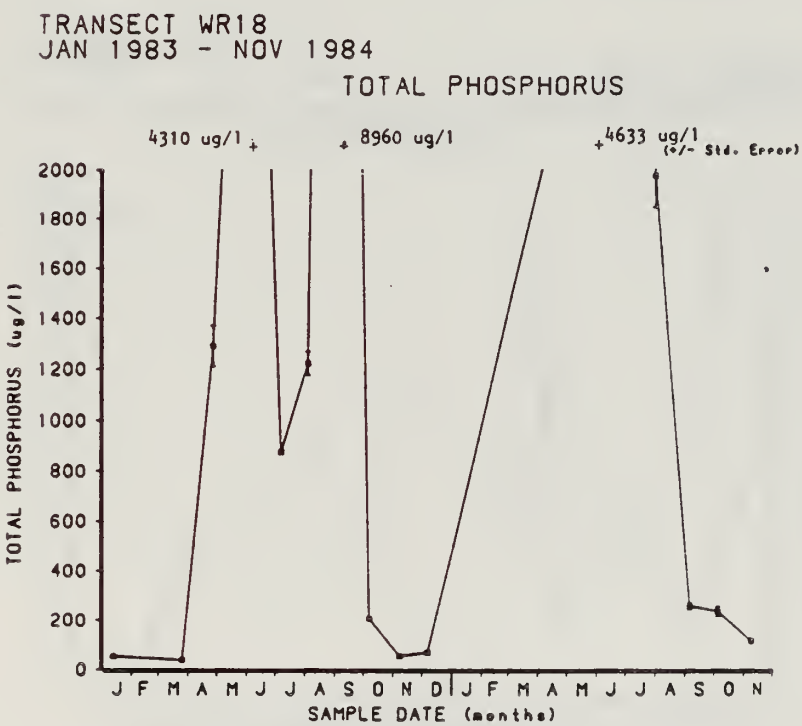
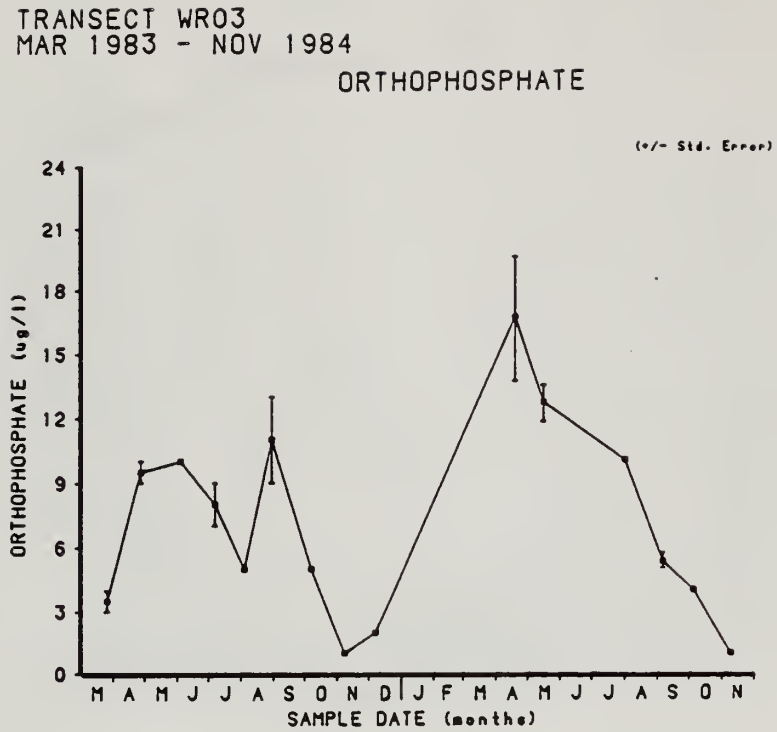


Figure 4.4-7. Concentration of total phosphorus for White River Transects WR03 and WR18 during 1983 and 1984.



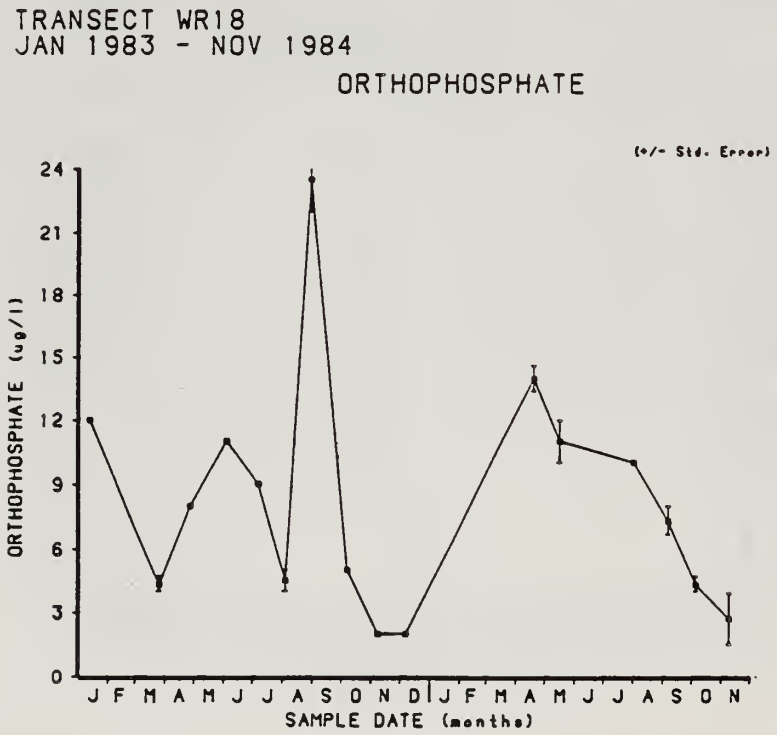
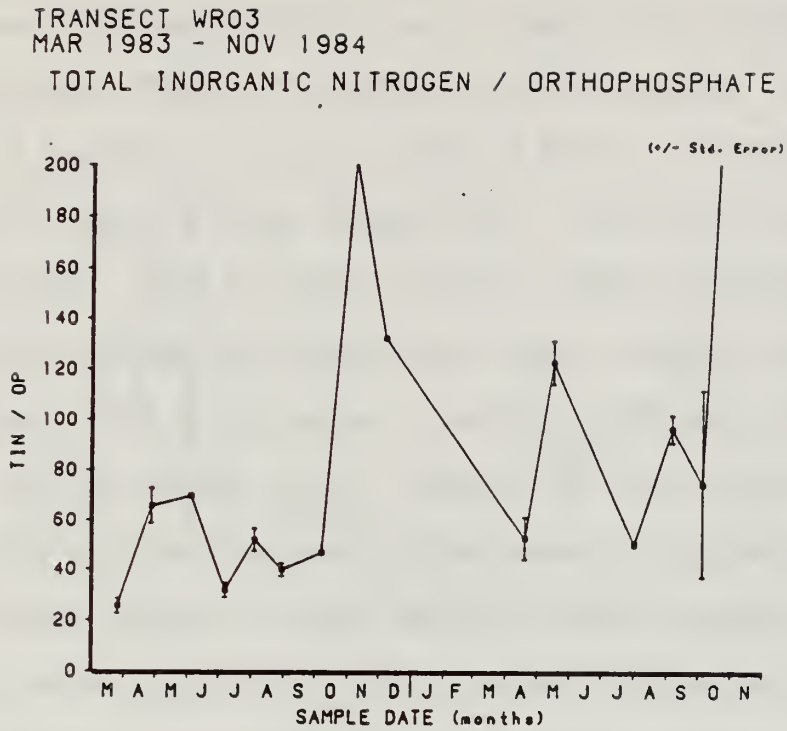


Figure 4.4-8. Concentration of orthophosphate for White River Transects WR03 and WR18 during 1983 and 1984.



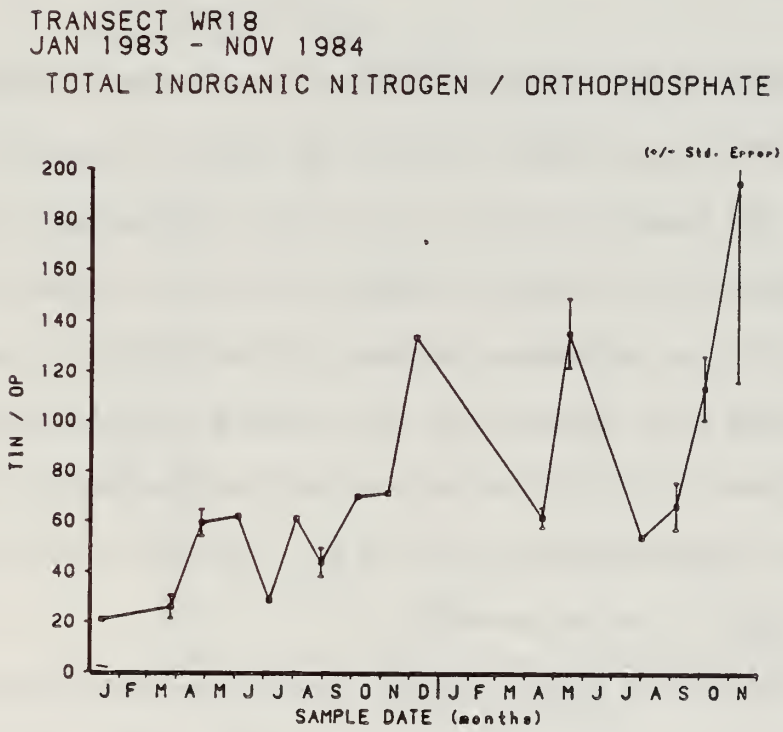


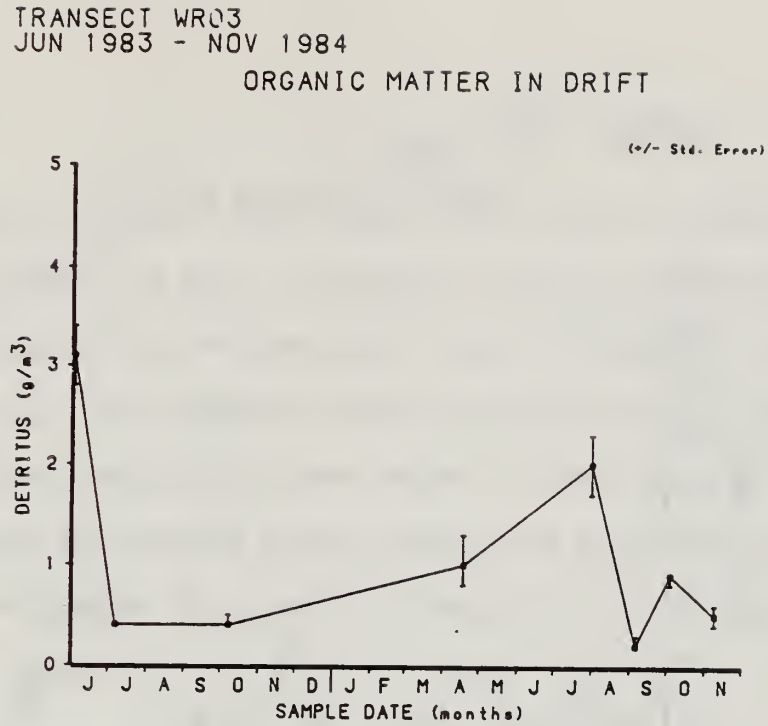
Figure 4.4-9. Total inorganic nitrogen to orthophosphate ratio for White River Transects WR03 and WR18 during 1983 and 1984.

4.4.3 The Organic Environment

Organic matter within streams is an important source of energy for many stream organisms. Sources of organic matter are either external (terrestrial) and enter the river with surface flow, or are internal and are produced within the river (aquatic). This organic matter resides in two dominant compartments defined by Cummins (1974) as CPOM and FPOM. CPOM, or coarse particulate organic matter, taken here as particles greater than 1 mm in size can be processed by physical abrasion or animals into FPOM, fine particulate organic matter, less than 1 mm in size. In the aquatic biology monitoring program three parameters are measured to characterize the organic environment. These are organic matter drifting (DRIFT), benthic organic matter associated with invertebrate samples (CPOM) and organic matter contained in the interstitial sediment (FPOM) available to burrowing invertebrates and microbes.

Drifting organic matter through 1983 has been measured somewhat crudely as total coarse particulate matter drifting per hour. This constitutes an approximation to the amount of drift only in that samples were taken for similar time periods and in areas of similar velocity. Based upon characteristics of the drift nets determined during 1983 (WRSOC 1983), samples taken during 1983 and 1984 were standardized to discharge (gm/m^3) (Figure 4.4-10). During these two years, drifting organic organic matter passing through the study section has varied between 0.3 gm/m^3 and 3.0 gm/m^3. Peak values correspond with high discharge periods.

The amount of benthic organic matter (CPOM) associated with macroinvertebrate samples is shown in Figure 4.4-11. The general pattern of



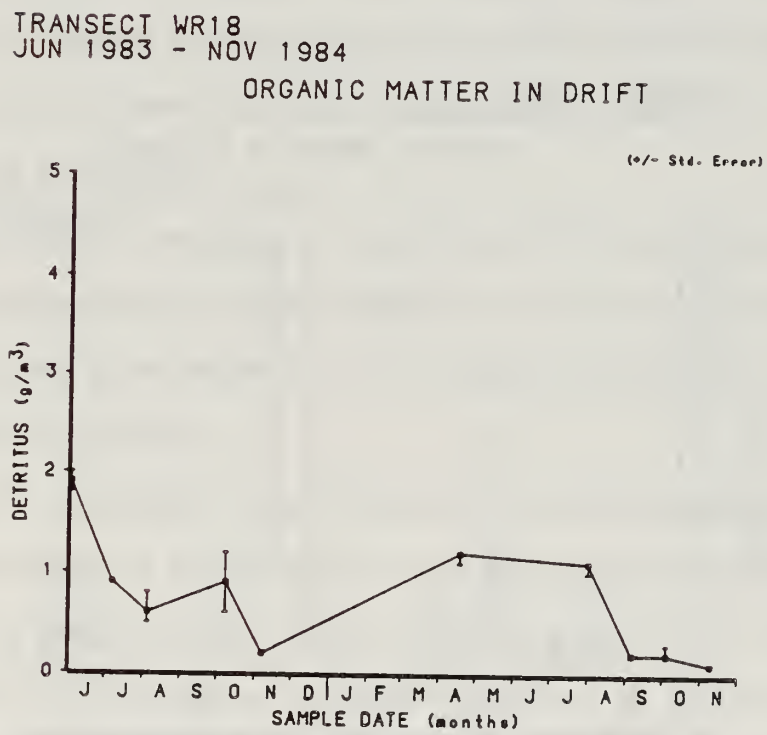
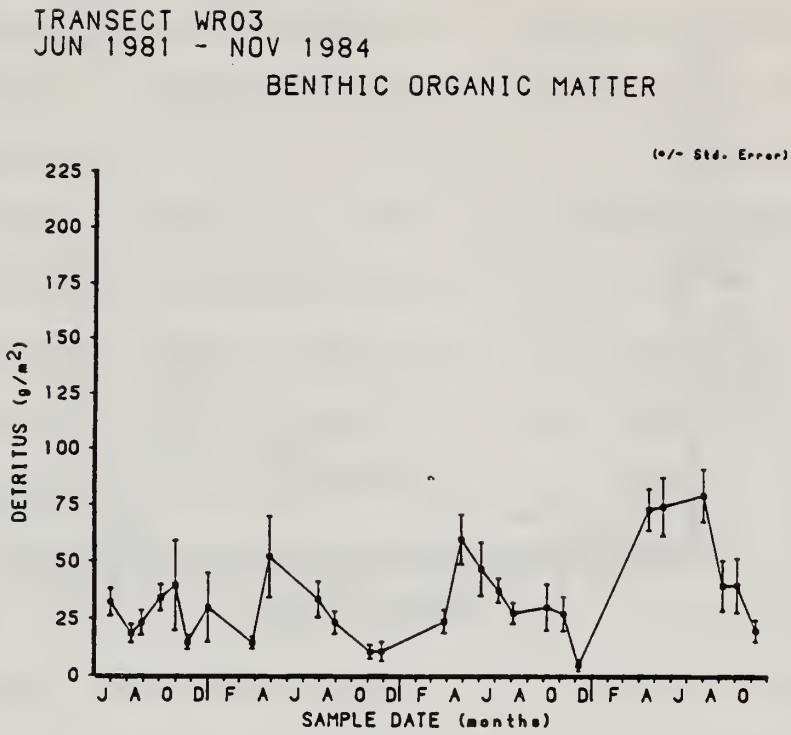


Figure 4.4-10. Organic matter drifting in the water column at White River monitoring Transects WR03 and WR18 during 1983 and 1984.



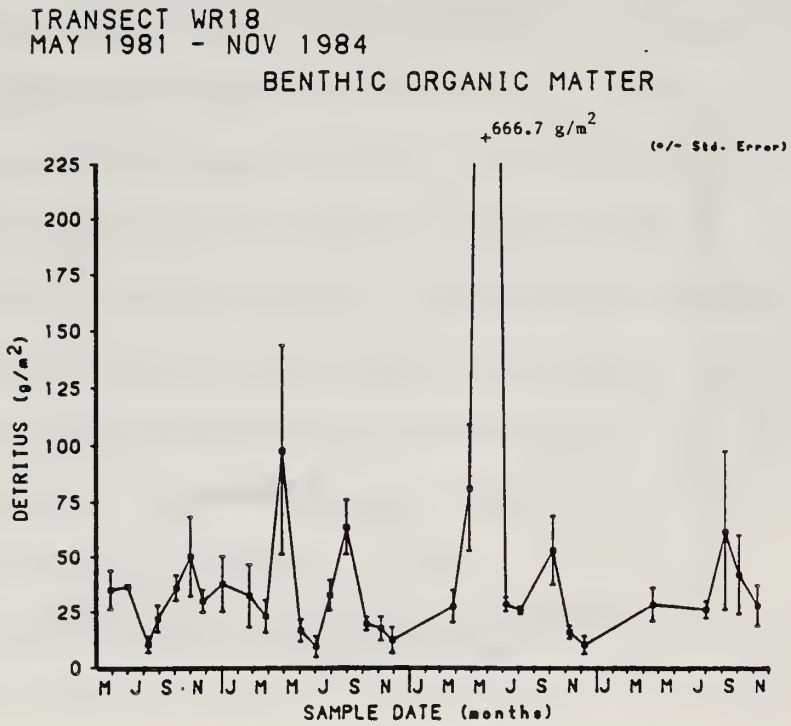


Figure 4.4-11. Benthic organic matter (CPOM) contained in macroinvertebrate samples for White River Transects WR03 and WR18 from May, 1981 to November, 1984. Each data point is the mean of five samples taken along the transect.

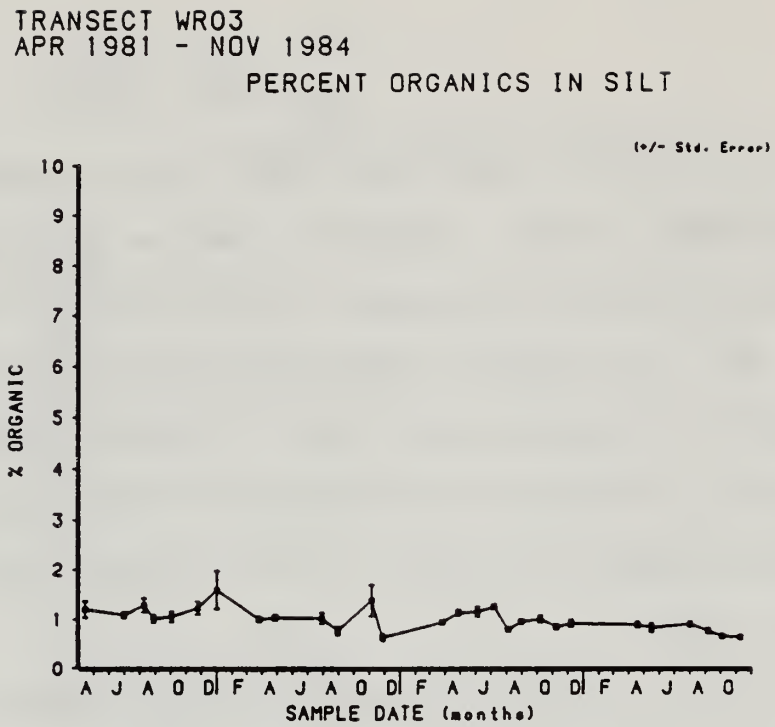
CPOM consists of high values as lower basin runoff occurs, gradually declining through summer and fall. Exceptions occur due to periodic inputs from storms or during periods of warm water with low turbidity such as June through October, 1981. The abnormally high data points during early June, 1983 at WR18 resulted from sampling near shore in a shallow area which had trapped large amounts of floating debris during this high flow period. Barring this abnormal point the dynamics of benthic organics have been similar during all years.

Interstitial sediment organic matter (FPOM) has maintained a level near 1% of the sediment size fraction less than 0.25 mm at all transects during the period April, 1981 until November, 1984 (Figure 4.4-12). Periodic increases occur in response to runoff events, either lower and upper basin or storm events. This pattern has been most evident on WR18.

4.4.4 Primary Producers

The primary producers or algae in the White River constitute a second important energy source for the other trophic levels residing there. The algal community in the White River is quite diverse and appears to be regulated by physical factors.

The pattern of chlorophyll a as a measure of periphyton biomass in the White River is presented in Figure 4.4-13. It was suggested in WRSOC (1983) that algal standing crops were driven by available light in the White River. As light increased, algal standing crops were observed to increase except when scouring by silt occurred during high flows or ice occurred during the winter months. It has been observed that in November and December when ice is beginning to form in the river that the freshly formed ice crystals and



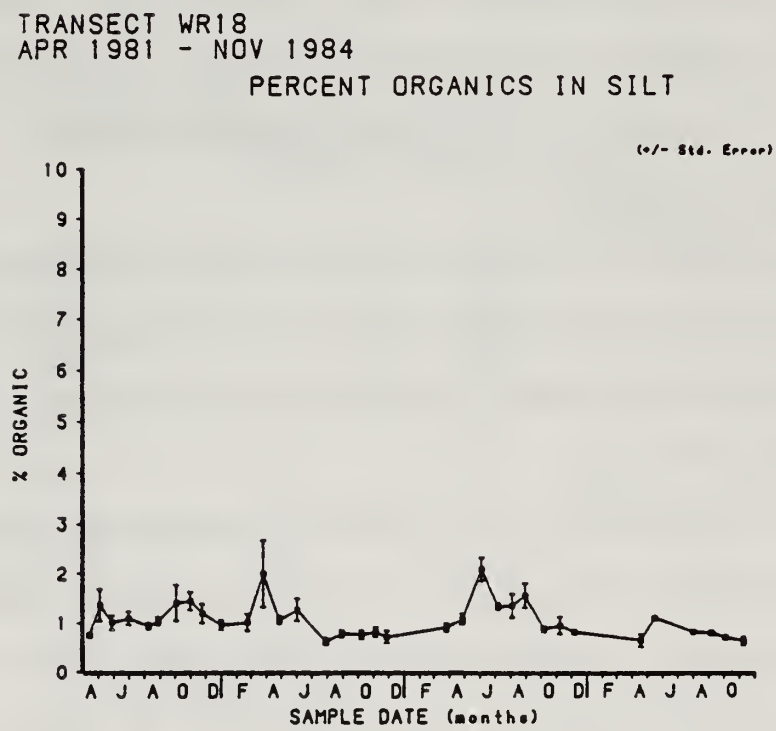


Figure 4.4-12. Sediment organic matter (FPOM) as a percent of the (-0.25mm) sediment size fraction for White River Transects WR03 and WR18 from April, 1981 to November, 1984.

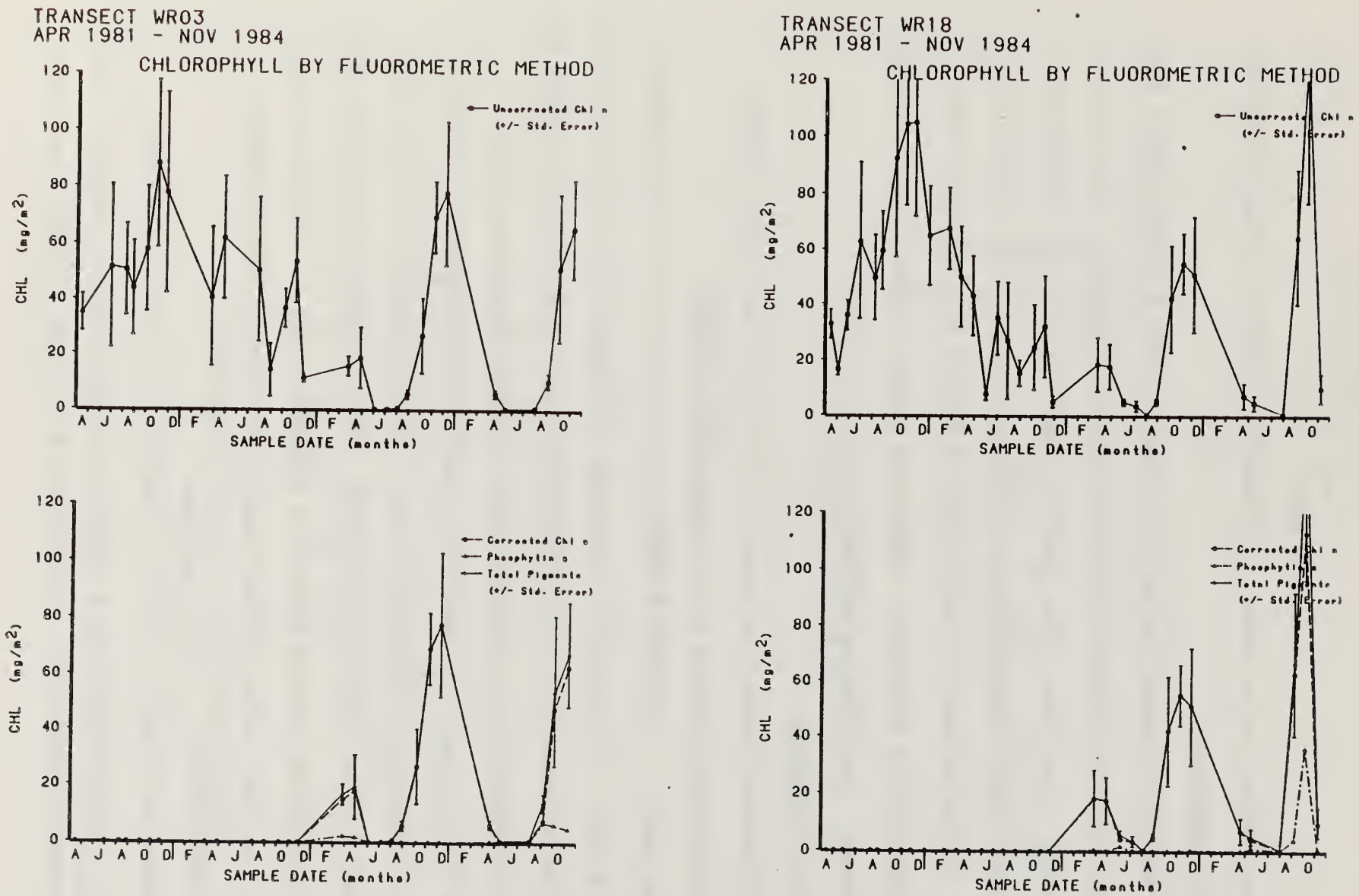


Figure 4.4-13. Periphyton biomass as chlorophyll a for White River Transects WR03 and WR18 from April, 1981 to November 1984.

subsequent anchor ice may scour the streambed, removing a large portion of the algal community.

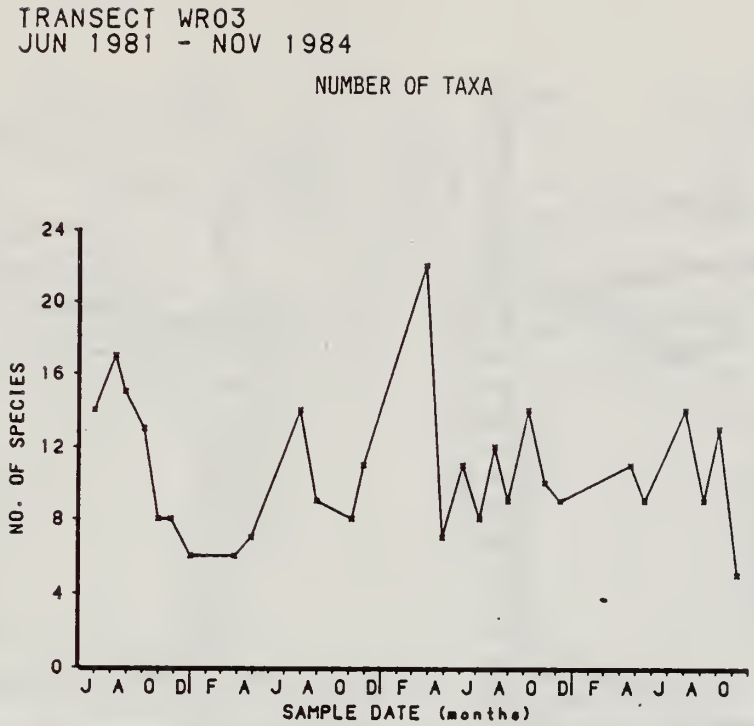
The periphyton biomass measured on transects WR03 and WR18 reflect these patterns well with increasing algal crops occurring parallel with increasing light levels in the river. The greatest algal biomass occurs following 2 or 3 months of reduced suspended solids loads, generally during fall or early winter. During periods of scouring with or without high available light algal standing crop decreases. Comparisons between transects WR03 and WR18 are discussed in a following section.

4.4.5 Consumers

The consumer community measured in the White River aquatic biology monitoring program consists of the stream invertebrates.

The number of invertebrate taxa varies widely over short time periods (Figure 4.4-14). This reflects losses due to emergence and drift as well as gains from upstream drift and reproduction. There is no distinct pattern to number of taxa over time although richness appears to increase during periods of increased light penetration, particularly following upper basin runoff as temperatures are also rising. Richness generally declines with the onset of winter and icing conditions. WR03 and WR18 have exhibited this pattern and during previous years have attained maxima of 16 or more taxa. Richness was lower during 1984 with maxima of 12 and 14 taxa at WR18 and WR03, respectively.

Numbers and biomass of benthic invertebrates occurring on riffle transects continued to follow a pattern of increase during periods of high light penetration and lower flows (Figures 4.4-15 and 4.4-16). Peak flows



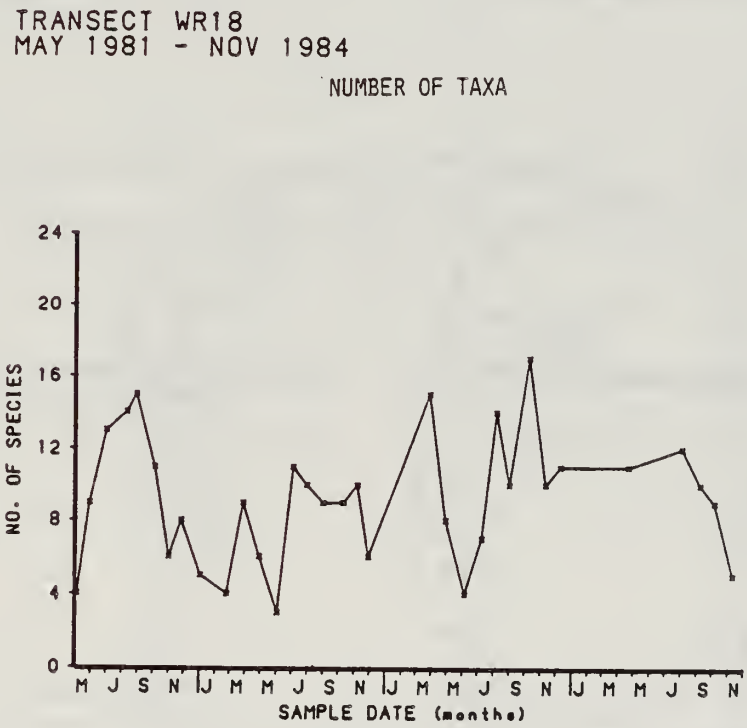


Figure 4.4-14. Taxonomic richness of the benthic macroinvertebrates community for White River Transects WR03 and WR18 from April, 1981 to November 1984.

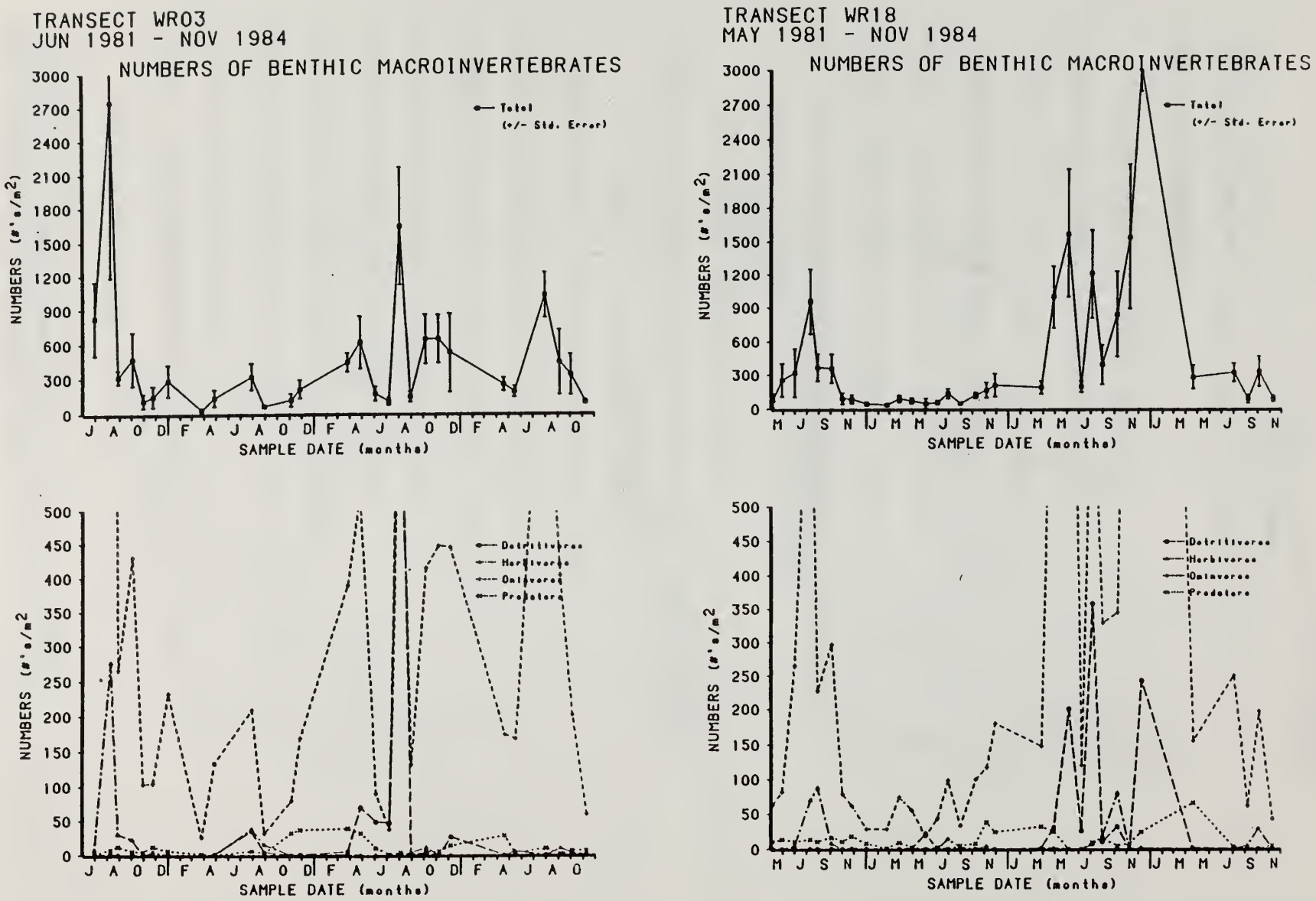


Figure 4.4-15. Numbers of benthic macroinvertebrates by functional group and totals for White River Transects WR03 and WR18 from April, 1981 to November 1984.

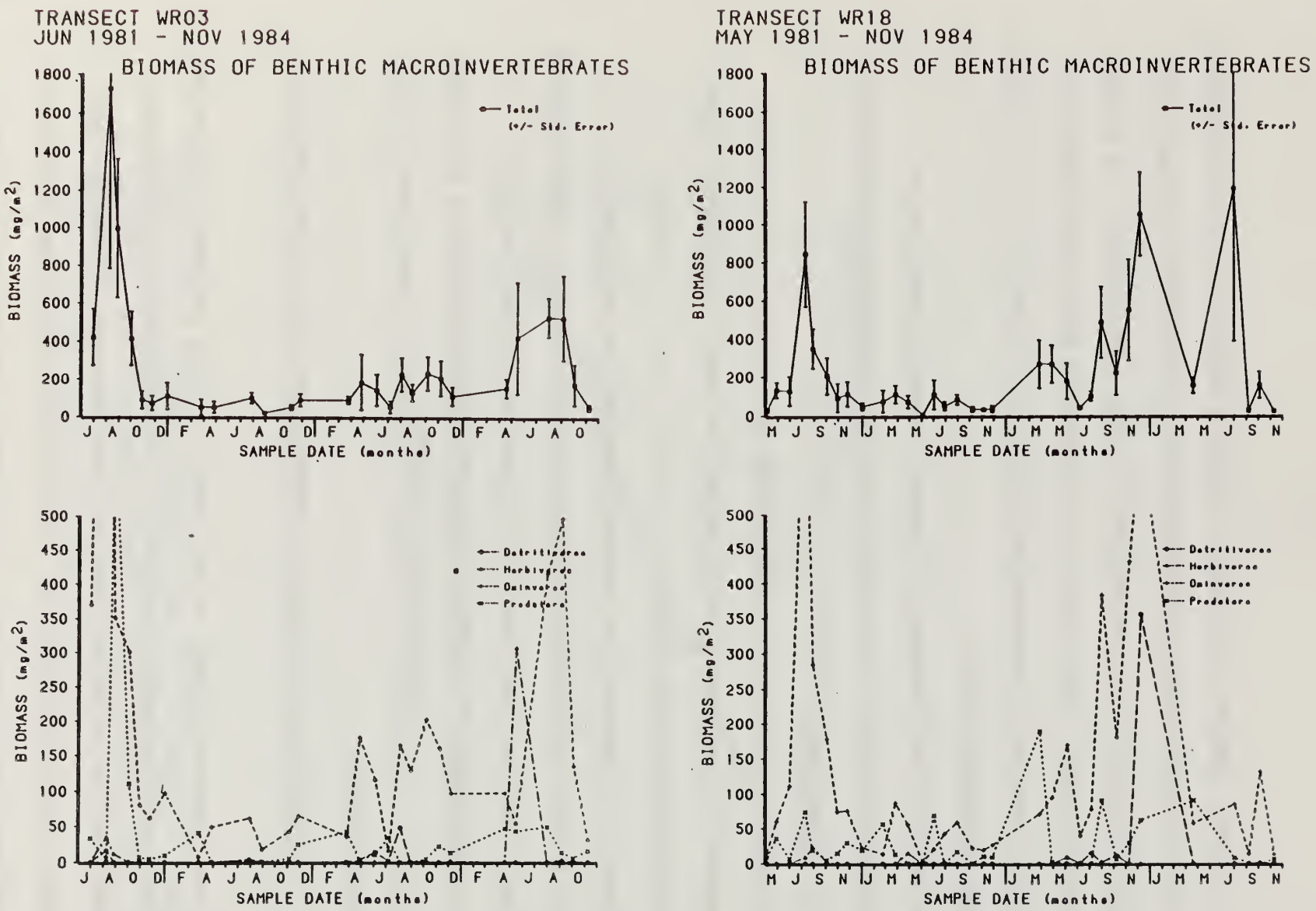


Figure 4.4-16. Calculated biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR03 and WR18 from April, 1981 to November, 1984.

generally depress numbers and biomass, probably through increased downstream drift. During 1982, numbers and biomass were low throughout the year while in 1983 and 1984, both years of greater flow than 1982, numbers and biomass were generally higher. This could be an adaptation phenomenon, where the community has shifted to invertebrates with greater tolerance for high flows and greater suspended solids.

Functionally, the invertebrate community remains dominated by collector-gatherers and filter-feeding invertebrates which are omnivorous.

4.4.6 Decomposers

The index of decomposition used for the White River in the aquatic biology monitoring program is the decomposition rate of cottonwood leaves placed in leafpacks in the river.

Figure 4.4-17 contains the leafpack decomposition relationship developed in 1982. Data points from 1983 and 1984 are shown superimposed on this figure. 1983 and 1984 data points appear to fit the previously developed relationship. This lends support to this relationship as a good monitoring tool. Collection of additional data could increase the strength of this relationship.

4.4.7 Comparisons of Biological Parameters on Control and Treatment Sites

The most important aspect of the aquatic biology program is to monitor for changes in the biology of the White River due to oil shale development. Two transects within the White River are currently used to provide control and treatment sites for monitoring. Transect WR03 is situated above oil shale development activities and is considered to be the control site.

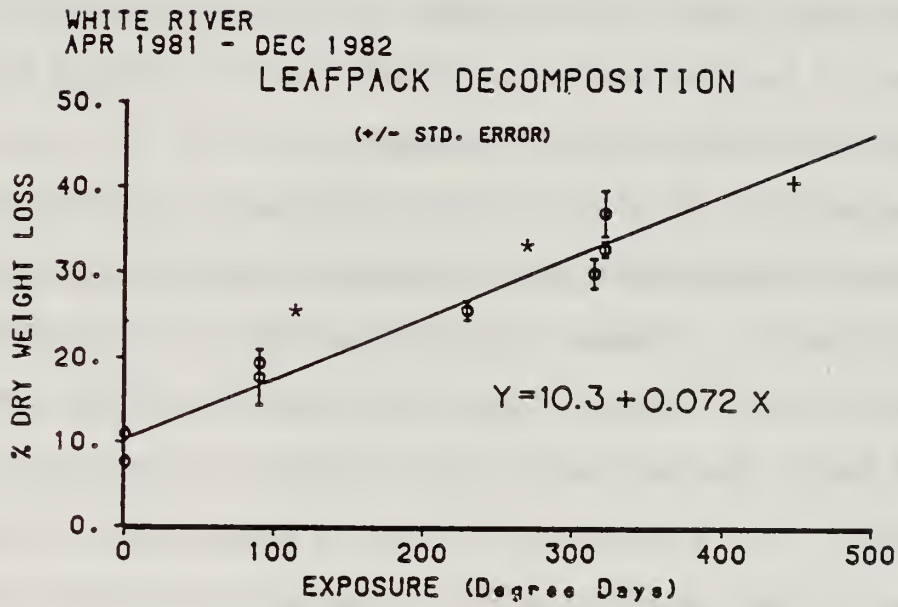


Figure 4.4-17. Leafpack decomposition for leafpacks at Transect WR18 in the White River. Relationship developed from leafpacks placed in the river during October, 1981 to March, 1982. Data shown with an asterisk (*) are for leafpacks in 1983. The single data point for 1984 is indicated with a (+).

Transect WR18 is located just below the plant site and is considered the treatment site for Tracts Ua and Ub. Differences between WR03 and WR18 should occur if the aquatic ecosystem is being affected by oil shale development at Tracts Ua and Ub.

At the present time, three operational biological parameters are being used to monitor impacts on the aquatic biology of the White River - the numbers of macroinvertebrates (numbers/m^2), the biomass of macroinvertebrates (mg/m^2) and the amount of chlorophyll a (mg/m^2).

The mean of the five samples collected at specific points along each transect are used as data for each parameter.

Two way analysis of variance (ANOVA) techniques were used to test for differences in these parameters by transect and over time. As with many biological parameters, the mean and standard deviation of the estimates of these parameters are related. To meet the assumption of equal variances required by ANOVA, the sample data were transformed using the Ln(x) transformation. This transformation assumes a linear relationship between the mean and standard deviation which was appropriate for these data.

The hypotheses tested using the ANOVA techniques for each parameter were:

H_{01}: There is no difference in the parameter value at each transect.

H_{02}: There is no difference in the parameter value on each sampling date.

The alternate hypothesis for each of these was that at least two of the samples were significantly different. Data were selected from the six dates

during 1984 when samples were collected from each transect.

The results of the two-way ANOVA for the biomass of macroinvertebrates are shown in Table 4.4-3. This analysis shows that macroinvertebrate biomass did not differ between transects but that during one or more months, biomass was significantly different from all others. A multiple comparisons test was conducted using Fisher's least significant difference test to determine which dates were different. This analysis showed that invertebrate biomass during July, 1984 was significantly higher than all other months sampled.

The results of the ANOVA conducted for macroinvertebrate numbers is shown in Table 4.4-4. As with biomass, numbers of macroinvertebrates did not differ between transects but numbers were significantly higher during July, 1984 than in all other months sampled except April. The July, 1984 difference in macroinvertebrate numbers and biomass was due to a large number of annelid worms which were only present in samples from a shallow water zone on transect WR18.

Table 4.4-5 displays the results of the two-way ANOVA conducted on chlorophyll a data. No difference was found between transects. Differences were found between sample dates. September and October, 1984 had significantly higher chlorophyll a concentrations than all other months sampled during 1984.

An anomaly in the data appeared with the November, 1984 chlorophyll a values. The chlorophyll a values at WR18 were greatly reduced from the previous month while those at WR03 remained high. This appeared to be due to both an artifact of sampling and subtle physical changes taking place at

Table 4.4-3. ANOVA for the biomass of macroinvertebrates.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	1	3.28	1.03	0.3163 N.S.
Date	4	13.48	4.29	0.0056
Error	40	3.14		

Table 4.4-4. ANOVA for the numbers of macroinvertebrates.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	1	2.86	2.44	0.1262 N.S.
Date	4	5.77	4.93	0.0025
Error	40	1.17		

Table 4.4-5. ANOVA on chlorophyll a.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	1	0.30	0.13	0.7200 N.S.
Date	5	40.92	18.68	0.0000
Error	48	2.19		

WR18. Random sampling during this time period resulted in no shallow water samples being taken at WR18. In addition, WR18 appears to be cutting down at the north bank resulting in a deeper channel with a lower lignt level at the substrate. The combination of these two factors probably resulted in the lower chlorophyll a values at WR18 as compared to WR03. It is recommended that future sampling be stratified into deep water and shallow water zones, thus eliminating this problem.

4.5 References

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Chapter 5.0

5.0 TERRESTRIAL FAUNA

5.0 TERRESTRIAL FAUNA

5.1 INTRODUCTION

The terrestrial wildlife monitoring program was designed to assess the impacts of development related activities on the terrestrial biota of WRSOC Tracts Ua-Ub. The 1982 Environmental Monitoring Mannual (EMM) was developed to identify impacts to terrestrial fauna resulting from construction and operations activities. In 1984, the third year of development related activities on the tracts, the monitoring program emphasized three groups of terrestrial organisms: foliage invertebrates, birds, and mammals. Reptiles, which have been part of the program since 1975, were not systematically studied. This report describes the species composition, abundance, distribution, and community characteristics of each group studied. Changes in these parameters over the years of the study are discussed and related to changes in physical environmental variables.

5.2 SUMMARY

5.2.1 Foliage Invervetrabes

During 1982-1984, 265,364 invertebrates from beat samples were collected and enumerated. Of the functional groups, sap-feeders were most abundant, followed by saprophores, predators, leaf-chewers, and others. Foliage invertebrate abundance, biomass and richness increased on all host plants and transects from 1982-1984, with some increases being quite large from 1983-1984. These increases were ultimately related to increases in precipitation during the same period of time.

Mean foliage invertebrate abundance, biomass and richness of big sagebrush along different transects were positively correlated with leaf water potential along the same transects (r= 0.81, 0.64 and 0.84 respectively).

The same faunal characteristics and leaf water potential were negatively correlated (r= -0.75, -0.93, and -0.87 respectively; r= 0.77 for leaf water potential) with ground slope; steeper slopes had lower leaf water potential and fewer foliage invertebrates. These data suggest that the topographic characteristics of the spent shale pile will have an important effect on water stress to the plants and thus the invertebrate faunas.

5.2.2 Birds

Bird species richness (70 species) and composition in all habitats in June, 1984 were similar to that observed in June 1982 and 1983. Consuming biomass ranged from 264 to 312 g/20 ha in the upland habitats but was much greater in Riparian habitat (2438 g/20 ha). Granivores dominated the bird communities on the upland habitats whereas insectivores dominated in Riparian.

Even through the breeding bird community did not change markedly from 1983 to 1984, the distribution of species and biomass among trophic groups and guilds changed significantly. This result is consistent with results of the baseline study: the avian community does not vary markedly over the time but change in community components reflect trends not observed at the community level.

Waterfowl abundance along the White River was 2.1 individuals/river km, slightly lower than that recorded in 1982 and 1983.

Thirteen active raptor nests were located in 1984. Red-tailed hawks (6 nests) and golden eagles (4 nests) were the most common breeders. One breeding pair of prairie falcons and 2 pairs of great horned owls were found. Reproductive success was lower in 1984 than in 1983, probably due to a decrease in abundance of desert cottontails an important prey species.

Density of breeding raptors in 1984 was lower than that observed in 1983 and similar to that observed in 1982. During the February bald eagle survey, 22 individuals were located, more than in either 1982 or 1983.

5.2.3 Mammals

Twenty-seven species of mammals were seen on tracts Ua-Ub in 1984, including 10 rodent, 5 carnivore, and 4 domesticated species.

Rodent communities in each of the four habitats on Ua-Ub changed markedly between 1982 and 1984. On Juniper and Riparian study sites in particular, rodent density, richness, and species diversity have decreased markedly since 1982. Changes in Riparian are likely the result of the severe winter of 1983-1984 and a flash flood in August 1982, which deposited several inches of sediment on the rodent-trapping grid.

The desert cottontail population declined significantly during the winter of 1983-1984. In August 1983, average densities were about 2 or 3 ind/ha. By the spring of 1984, the largest populations remained in Shadscale with 0.15 ind/ha.

Mule deer abundance in 1984 was about 0.20 deer/km of transect. This value was intermediate to the 1982 (0.11 ind/km) and 1983 (0.24 ind/km) populations.

5.3 PROGRAM DESCRIPTION

5.3.1 Objectives

Objectives in 1984, were to identify differences in bird and mammal populations between the 1975-1981 baseline period and 1984 data. The second objective was to determine whether the changes for differences identified were caused by natural changes in the environment (e.g., precipitation) or were related to tract development activities. For the foliage invertebrate monitoring program, objectives were to establish general faunal patterns

(year-year, seasonal, habitat, host plant), and identify important environmental factors determining invertebrate faunal structure.

5.3.2 Sampling Locations

Sampling locations are shown in Fig. 5.3-1. The eight transects shown were sampled for foliage invertebrates, birds, and mammals. Precipitation on tracts from 1975 to 1984 is shown in Fig. 5.3-2.

5.3.3 Methods

Methods for most sampling are described in the Monitoring Manual (WRSOC 1982a). Additional methods are discussed below.

5.3.3.1 Foliage Invertebrates. All foliage invertebrate sampling was done with a beat net, at an intensity of 8 samples/host plant/transect (WRSOC 1984 and 1982). Big sagebrush was sampled in all transects, from May-Septemb ~. Other host plants were sampled only from May-July, and only in one transec of each vegetation type. Rubber rabbitbrush, greasewood and spiny hopsage ere sampled in WG-1, black sagebrush and juniper were sampled in WJ-1, shad: ale and spiny horsebrush were sampled in WS-1, and cottonwood was sampleo in WR-2.

Invertebrate abundance and biomass are reported as a cover estimate in terms of numbers and biomass per m^2 of shrub. Previously (1982-1983), a volume (m^3 of shrub) estimate was used. The reason for this change is discussed in Section 5.4.1.5. Mean abundance was calculated by dividing the number of invertebrates by the area (m^2) of each shrub, then taking the average of the 8 samples from a transect. Biomass was calculated by dividing the total biomass (mg) by the total area (m^2) of the 8 shrub samples from a transect.

Soil water potential data (pre-dawn) were collected according to procedures described in WRSOC (1984). Leaf water potentials (pre-dawn) were sampled only on big sagebrush. Calibration of the psychrometers was done

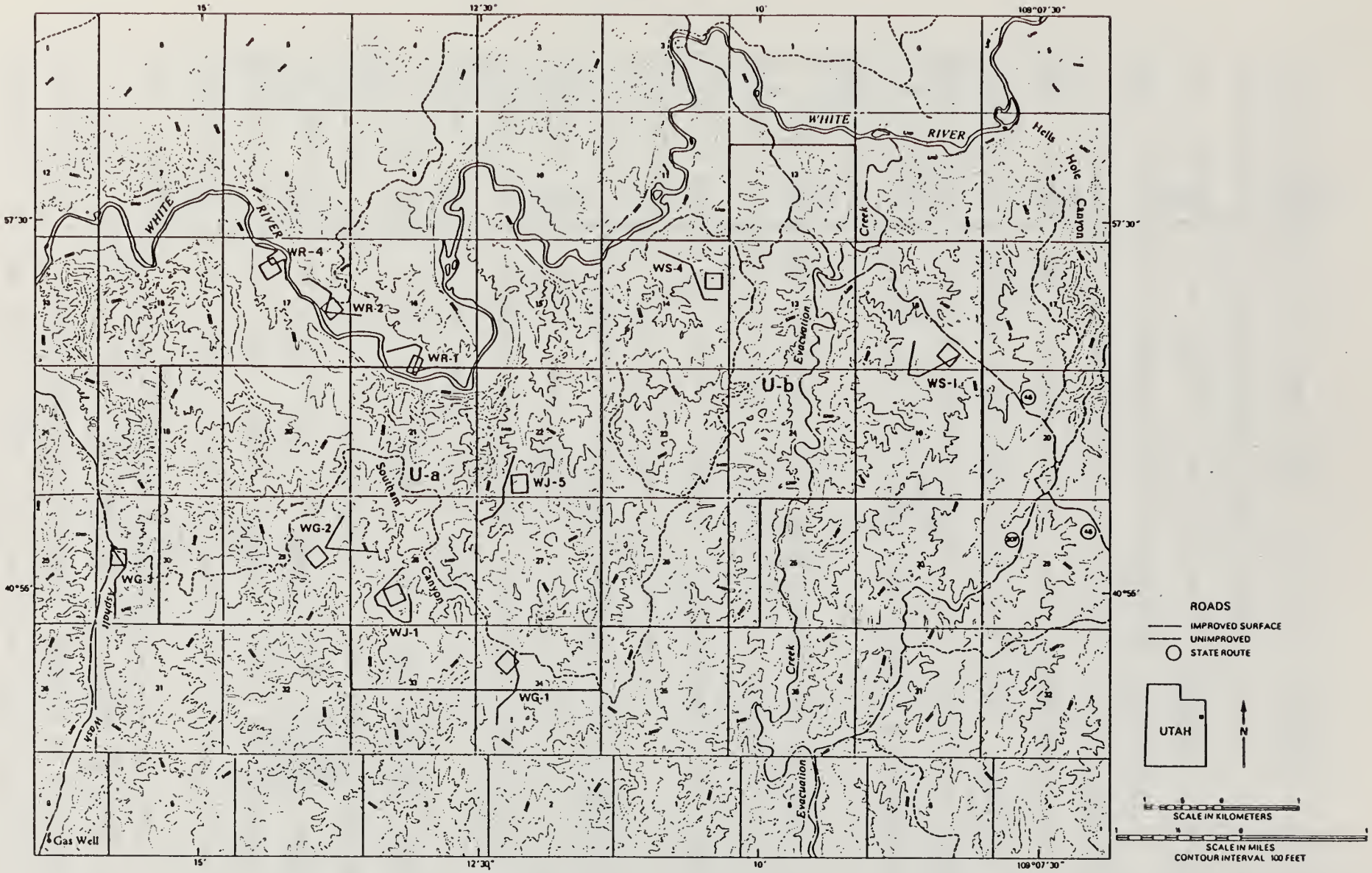

Fig. 5.3-1 Sampling locations on and near Tracts Ua and Ub. Solid lines are 1 km flushing transects; squares are rodent-trapping grids. Site designations are: WG, Greasewood; WJ, Juniper; WS, Shadscale; WR, Riparian. Transects WG-2 and WR-4 were not sampled in 1984.

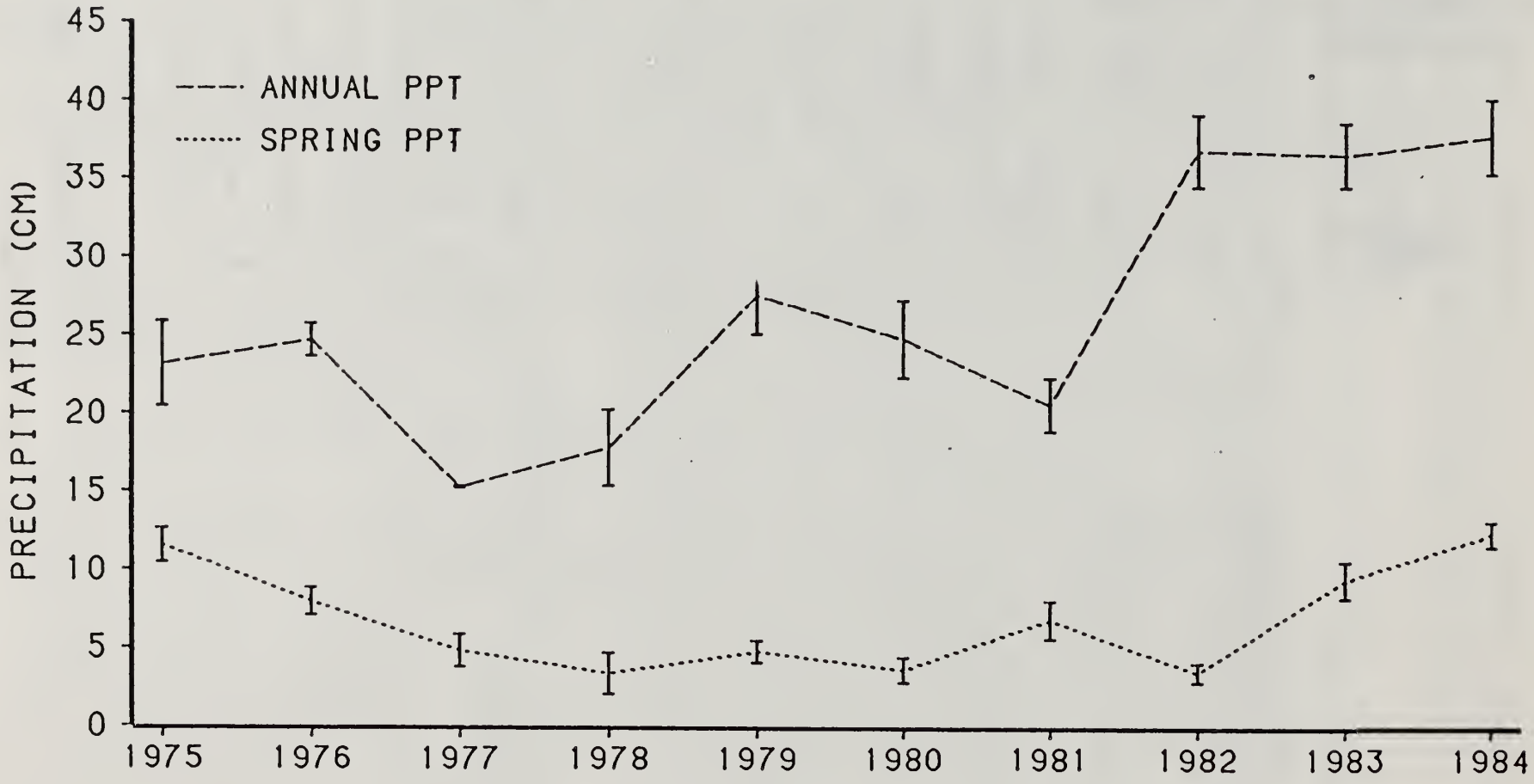

Fig. 5.3-2 Annual precipitation (water year) and spring precipitation (April-June) at Utah Oil Shale Tracts Ua and Ub from 1975 to 1984.

according to Brown and Bartos (1982). During the calibration process it was determined that the psychrometers (manufactured by Wescor Inc., Logan) were more sensitive to zero offsets than Brown and Bartos' model predicts, so the model was adjusted to compensate for this greater sensitivity.

For each big sagebrush sampled, percent slope of the ground immediately below the shrub was read with a Brunton pocket transit clinometer. Each shrub was then situated in the center of an 1 m^2 area. From this, % perennial cover, % annual cover, % litter cover, and % bare ground were estimated.

Grasshoppers were sampled in August according to procedures described in WRSOC (1984).

5.3.3.2 Birds. Breeding birds were censused during June. Differences between 1984 data and the baseline period are shown graphically by plotting consuming biomass and species richness and showing how these values compare to the 95% confidence intervals for the baseline period.

Abundance of migratory and nesting waterfowl along the White River was sampled on three 32.8 km canoe transects along the White River on 10, 11 and 12 April 1984. The numbers and species of waterfowl observed were recorded and their locations were mapped to the nearest 0.1 mile.

Known raptor nests were visited in April, June, and July, 1984. During these visits, suitable cliffs on and within 2 km of tracts Ua and Ub were searched for new nests. New nests were photographed and their physical and biological attributes (e.g., aspect, height on cliff, and vegetation type) were recorded. A bald eagle survey was conducted by helicopter on 22 February 1984. Locations of all bald eagles were mapped.

5.3.3.3 Mammals. Density of cottontails along each transect was calculated using the computer program "Transect". Details of this technique are described in Burnham et al. (1980). All mule deer sightings within 3 km

(rather than 1.6 km as stated in the Environmental Monitoring Manual) of Ua-Ub were recorded and mapped during 1984. Rodents were trapped on four rodent-trapping grids (WG-1, WJ-1, WS-1, and WR-2) during August.

5.4 PROGRAM RESULTS AND ANALYSIS

5.4.1 Foliage Invertebrates

Results of Foliage Invertebrate monitoring are divided into the following sections: Year-to-Year Trends, Host Plant Species, Vegetation Types and Transects, Causal Mechanisms, and Recommendations. The abundance, biomass, and richness of invertebrates were summarized on 9 host plants, and 4 vegetation types (8 transects) for 3-7 months, during 1982-1984. These are related to or correlated with soil moisture, soil water potential, leaf water potential and topography (slope). Complete lists of invertebrate taxa, faunistic indices (abundance, biomass, richness, diversity) and standard deviations are available from BRI or WRSOC.

Table 5.4-1 summarizes the total numbers of foliage invertebrates captured from beat net samples during 1982-1984. The most abundant taxa were the Aphididae, Psyllidae, Thripidae, Cicadellidae, Oribatidae, Tetranychidae, Miridae, Araneida, Sminthuridae, Coccoidea, and Curculionidae. Not evident from the table is the large contribution of the Acrididae to the total biomass. Relationships of these groups to leaf water potential are discussed more fully in section 5.4.1.4. The data in Table 5.4-1 and the following sections can be used as a guide in gauging rehabilitation of invertebrate faunas during rehabilitation of the spent shale pile. The invertebrate lists in 5.4-1 and 5.4-2 also reveal likely taxa or groups to be used as "indicators" of pollution and/or nutrient stress of plants.

5.4.1.1. Year-to-Year Trends. There have been general increases of foliage invertebrate abundance, biomass and richness on big sagebrush from 1982-1984. The increases between 1983 and 1984 were quite noticeable (Fig.

Table 5.4-1 Total numbers of individuals collected of the most abundant foliage invertebrate taxa, 1982-1984 (all beat samples combined). Different numbers of samples were taken each year, so these data should not be used as a year-year comparison. Functional groups, shown in parentheses, are: SF=sap-feeders, LC=leaf-chewers, SP=saprophores, PR=predators, DP=various Diptera (many leaf-miners), PA=parasitoids, FF=flowers feeders, OM=omnivores, NF=non-feeders.

Taxon	Year 1982	1983	1984	Percent of Total
Acarina				
Oribatidae (SP)	1538	7447	6834	6.0
Tetranychidae (SF)	2351	5031	7569	5.7
All Others	135	5	6	< 0.1
Araneida				
All (PR)	1394	3503	3374	3.1
Coleoptera				
Chrysomelidae (LC)	492	314	223	0.4
Cleridae (PR)	52	137	82	0.1
Coccinellidae (PR)	91	108	80	0.1
Curculionidae (LC)	322	1774	315	0.9
Lathridiidae (SP)	49	132	57	< 0.1
Leiodidae (LC)	47	43	19	< 0.1
Melyridae (PR)	15	23	2	< 0.1
All Others	79	54	51	< 0.1
Collemobola				
Entomobryidae (SP)	9	11		< 0.1
Sminthuridae (SP)	1599	1062	1003	1.4
Diptera				
Agromyzidae (DP)	188	405	115	0.3
Cecidomyiidae (DP)	112	121	21	0.1
Ceratopogonidae (PR)	60	131	146	0.1
Chironomidae (DP)	68	339	97	0.2
Chloropidae (DP)	20	194	47	0.1
Culicidae (PR)	3	1	132	< 0.1
Empididae (PR)	5	40	316	0.1
Ephydridae (DP)	61	166	4	< 0.1
Phoridae (DP)	4	63	4	< 0.1
Piophilidae (DP)	1	41	38	< 0.1
Sciaridae (DP)	104	198	13	0.1
Tephritidae (DP)	24	50	8	< 0.1
All Others	146	391	131	0.3
Ephemeroptera				
All (NF)	6	2		< 0.1
Hemiptera				
Anthocoridae (PR)	458	331	1139	0.7
Lygaeidae (SF)	38	176	36	< 0.1
Miridae (mostly SF)	3684	6696	3144	5.1
Nabidae (PR)	77	141	144	0.1
Pentatomidae (SF)	5	43	20	< 0.1
Reduviidae (PR)	25	56	54	< 0.1
All Others	5	4	7	< 0.1

Table 5.4-1, Continued

Taxon	Year 1982	1983	1984	Percent of Total
Homoptera (all SF)				
Coccoidea	376	1624	1339	1.3
Aphididae	18832	15674	37508	27.2
Cicadellidae	12531	16848	6471	13.5
Issidae	192	147	136	0.2
Membracidae	1	229	147	0.1
Psyllidae	978	10825	28980	15.4
All Others	8	267	323	0.2
Hymenoptera				
Chalcidoidea (PA)	65	289	622	0.4
Braconidae (PA)	72	152	60	0.1
Encyrtidae (PA)	474	136	91	0.3
Eulophidae (PA)	311	816	349	0.5
Formicidae (OM)	774	1247	445	0.9
Mymaridae (PA)	64	103	58	<0.1
Platygasteridae (PA)	163	363	113	0.2
Pteromalidae (PA)	254	557	257	0.4
Trichogrammatidae (PA)	185	36	50	0.1
All Others	105	55	55	<0.1
Lepidoptera (LC,FF)				
Macrolepidoptera		8	6	<0.1
Microlepidoptera	144	218	82	0.2
Coleophoridae	69	50	15	<0.1
Gelechiidae	23	457	214	0.3
Geometridae	31	27	26	<0.1
Pterophoridae		127	122	<0.1
All Others	361	386	870	0.6
Neuroptera				
All (PR)	107	64	50	<0.1
Odonata				
Lestidae (PR)	1			<0.1
Orthoptera				
Acrididae (LC)	27	127	278	0.2
Gryllidae (LC)	26	35	21	<0.1
Plecoptera				
Nemouridae (LC)		23	2	<0.1
Pseudscorpionida (PR)	1	3	3	<0.1
Psocoptera				
Liposcelidae (SP)	470	215	247	0.3
Psocidae (SP)	104	101	32	<0.1
Thysanura				
Machilidae (SP)	5	7	9	0.1
Thysanoptera				
Phlaeothipidae (PR)	95	312	141	0.2
Thripidae (SF)	10205	15676	14749	15.3
Unknown (NF, mostly eggs	3	711	775	0.6
TOTAL	60329	85158	119877	

Table 5.4-2 Total numbers of invertebrates in each functional group, 1982-1984 (all beat samples combined). Different numbers of samples were taken each year, so these data should not be used as a year-year comparison. See Table 5.4-1 for the major taxa which constitute each group.

	Year			
Group	1982	1983	1984	Total
Sap-Feeders	48327	61240	100430	209997
Leaf-Chewers	1421	3161	2058	6640
Saprophores	3948	9045	8227	21220
Predators	3307	4837	5672	13852
Parasitoids	1592	2259	1010	4861
Omnivores	774	1247	445	2466
Various Diptera	665	1941	473	3079
Flower Feeders	152	241	90	483
Non-Feeders	143	1151	1472	2766
Totals	60329	85158	119877	265364

* Tetranychidae (see Table 5.4-1) are included in the sap-feeders; in previous reports they were included in the leaf-chewers

5.4-1). Concomittant with these changes were increases in soil moisture (1982-1984) and soil water potential (1983-1984; Fig. 5.4-2). Late season (August-September) leaf water potentials however, were greater in 1983 than in 1984 (Fig. 5.4-2). Precipitation has generally increased over the period 1982-1984 (Fig. 5.3-2).

5.4.1.2 Host Plant Species. Invertebrate abundance increased on all host plants between 1983 and 1984, with some increases being quite large (Fig. 5.4-3 and 5.4-4). Increases in biomass during the same period were also quite large on most host plants (Fig. 5.4-5. and 5.4-6). Differences in richness between 1983 and 1984 were not very noticeable, except perhaps the greater levels in July 1984 compared to July 1983 (Fig. 5.4-7 and 5.4-8).

In general invertebrate abundance, biomass, and richness tended to peak during the leaf and flower stages of the plants, which was also the period of greater leaf water potential. Host plants which were less water-stressed (greater leaf water potential) had greater abundance, biomass and richness of invertebrates. WRSOC (1984) further discusses foliage invertebrte faunas, host plant phenology, and leaf water potential.

5.4.1.3 Vegetation Types and Transects. Increases in abundance, biomass and richness between 1982-1984 occurred in all vegetation types, but was most noticeable in the more mesic, Riparian and Greasewood habitats (Fig. 5.4-9 through 5.4-11). The general order, from greatest to least, of abundance, biomass and richness on big sagebrush was Riparian, Greasewood, Juniper, and Shadscale. This was the same order of leaf water potential (Fig. 5.4-12) and is discussed more fully in the next section. Table 5.4-3 summarizes mean monthly abundance, biomass, richness, leaf and soil water potential, and slope of big sagebrush, from 1982-1984.

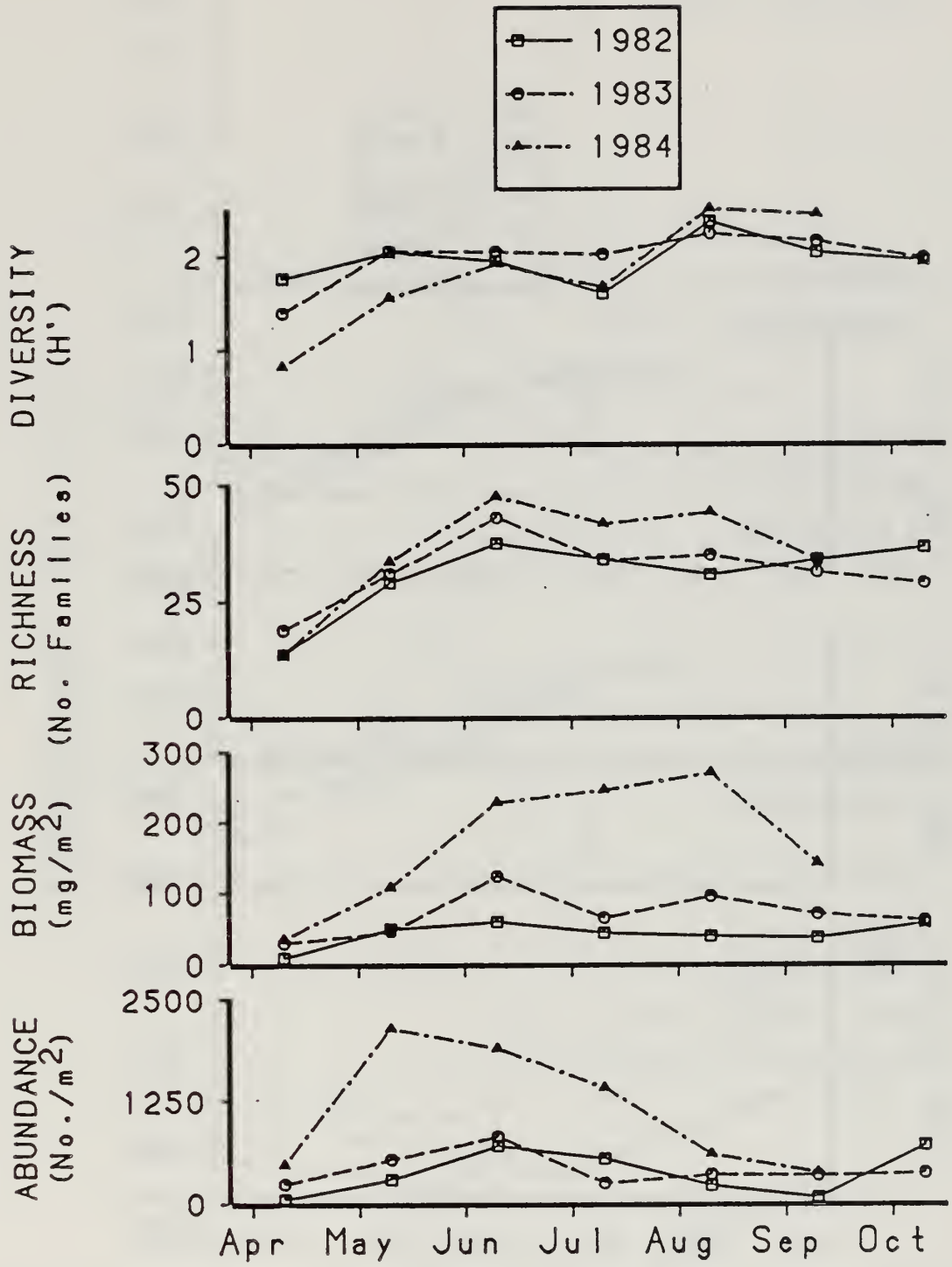

Fig. 5.4-1 Monthly changes in abundance (No./m^2 of shrub), biomass (mg/m^2 of shrub), richness (No. families/8 samples/transect) and diversity (H' for 8 samples/transect) of all invertebrates on big sagebrush, 1982-1984. Values are means for all 8 transects.

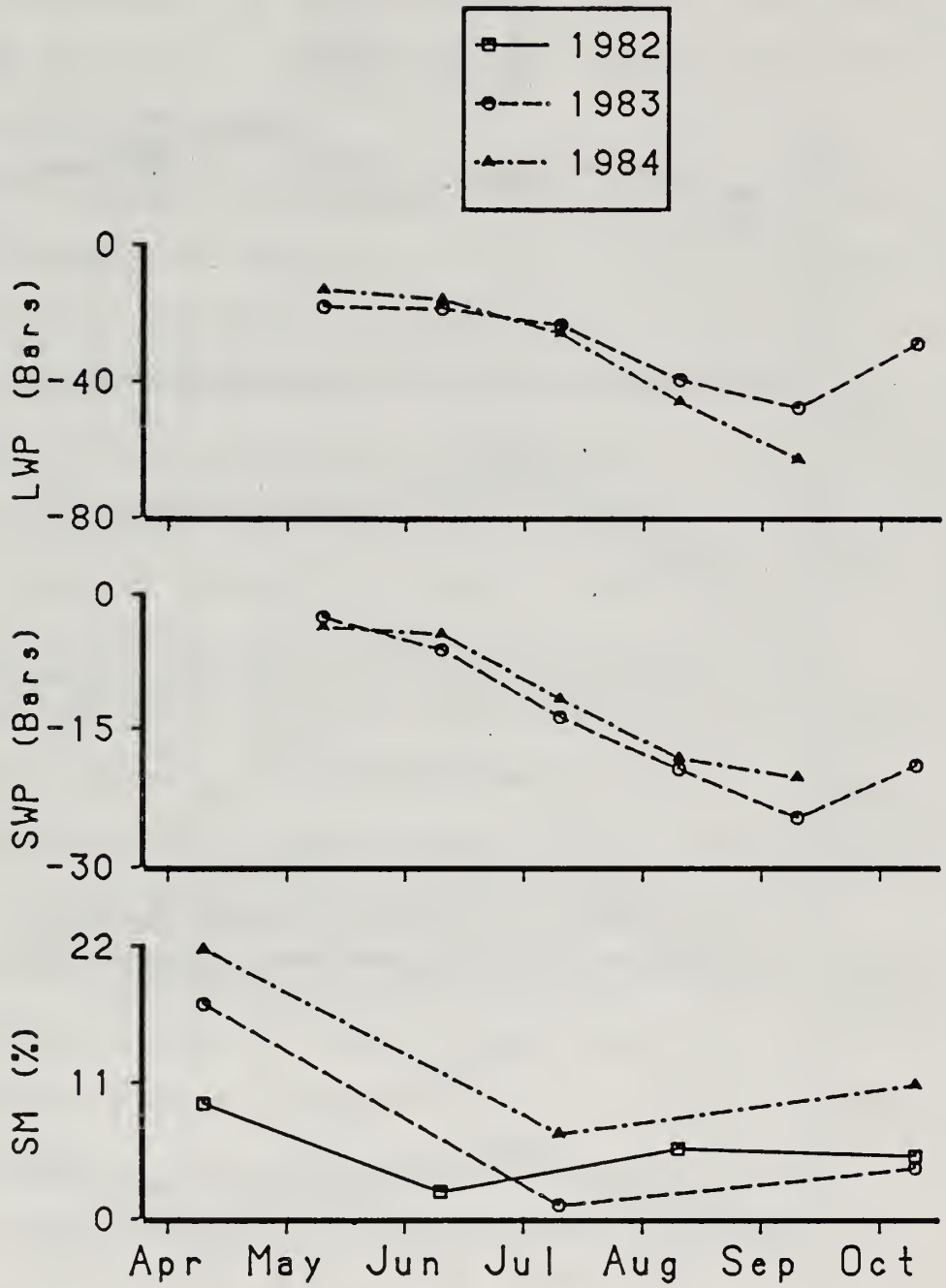

Fig. 5.4-2 Monthly changes in soil moisture (SM, %), soil water potential under big sagebrush (SWP, Bars), and leaf water potential of big sagebrush (LWP, Bars), 1982-1984. Values are means for all 8 transects. Soil moisture data were collected by Native Plants, Inc.

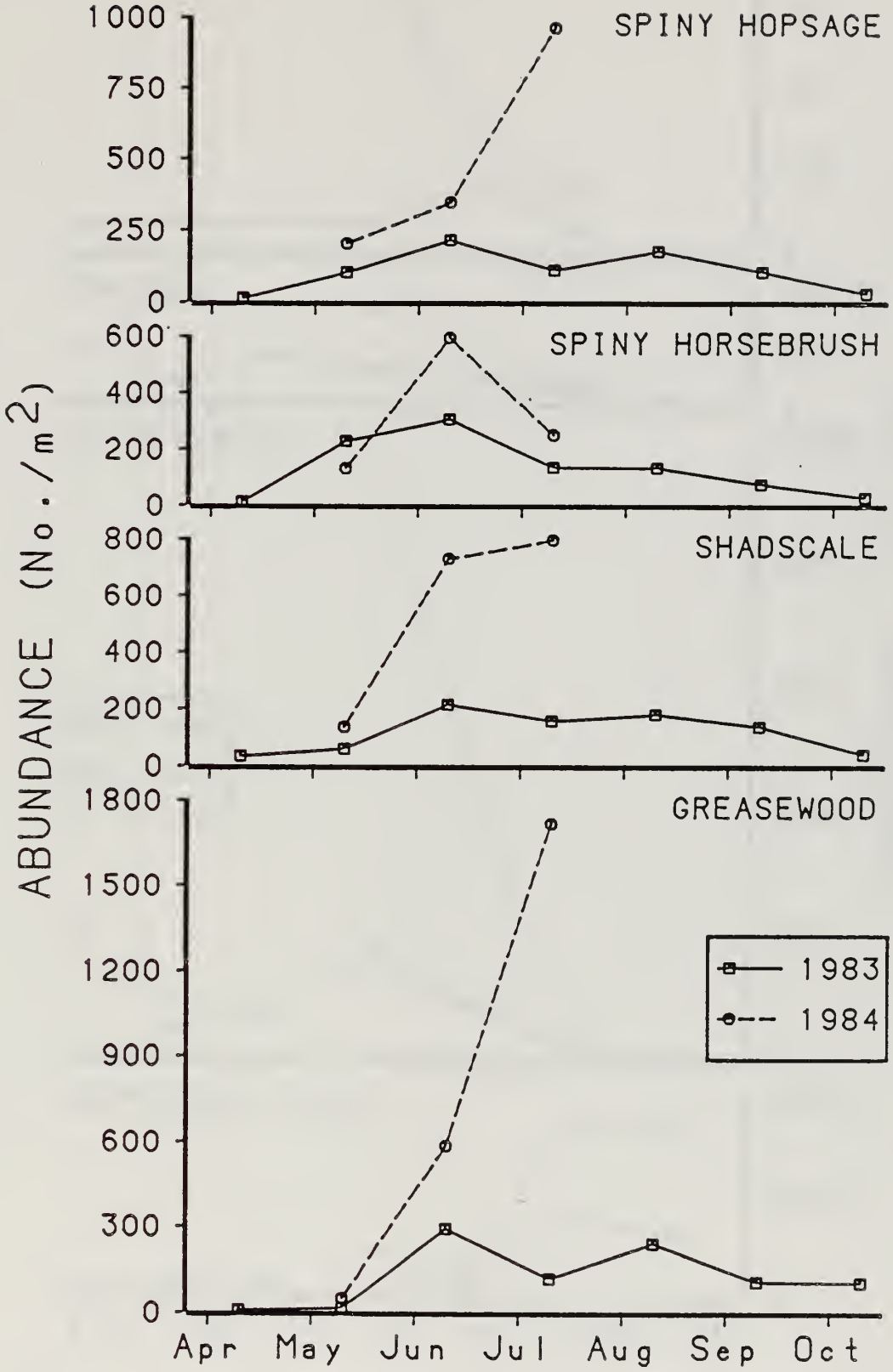

Fig. 5.4-3 Monthly changes in mean invertebrate abundance (No./m^2 of shrub) on four host plants, 1983-1984. Sampling locations were WG-1 for greasewood, WS-1 for shadscale, WS-1 for spiny horsebrush, and WG-1 for spiny hopsage.

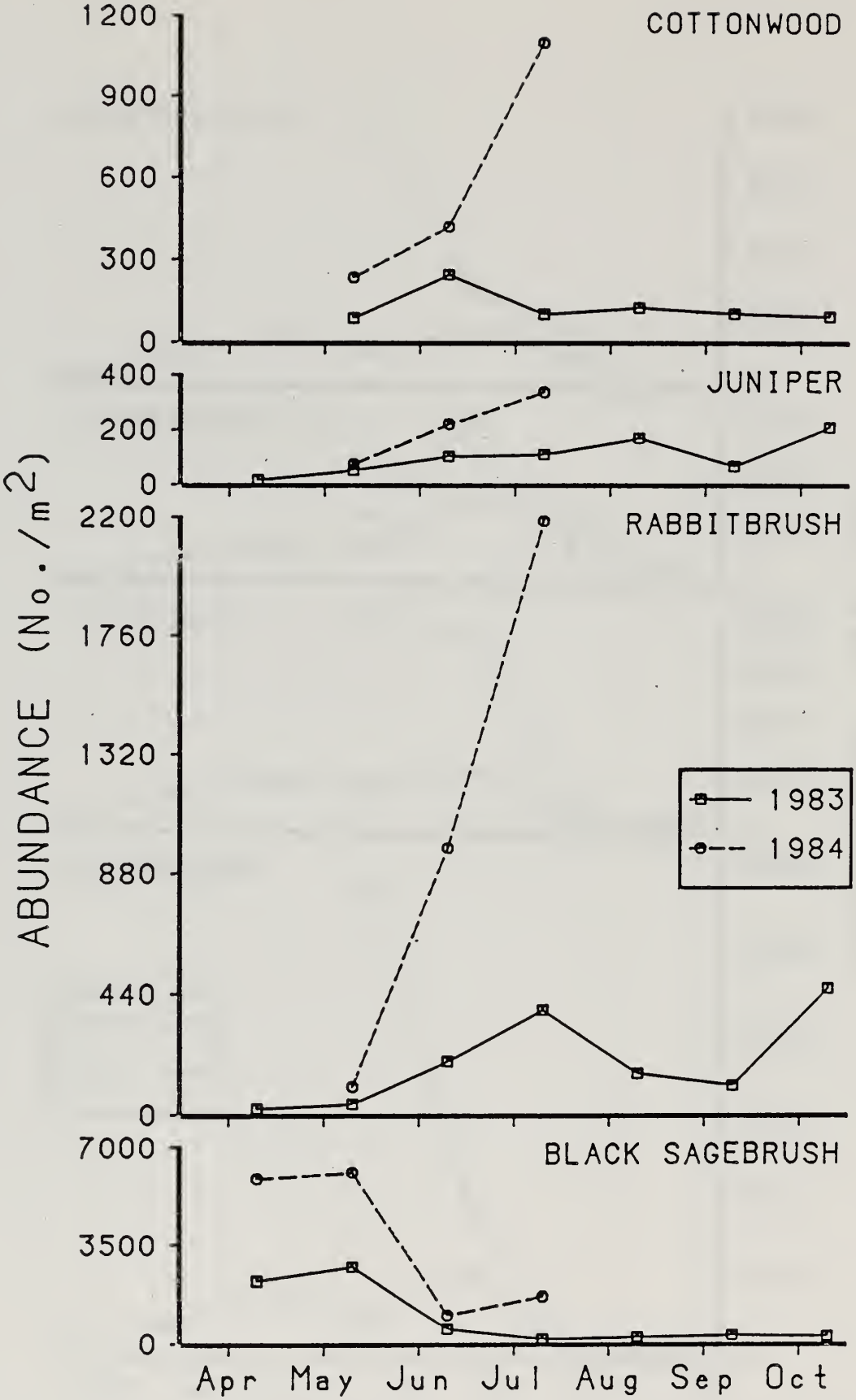

Fig. 5.4-4 Monthly changes in mean invertebrate abundance (No./m^2 of shrub) on four host plants, 1983-1984. Sampling locations were WJ-1 for black sagebrush, WG-1 for rabbitbrush, WJ-1 for juniper, and WR-2 for cottonwood.

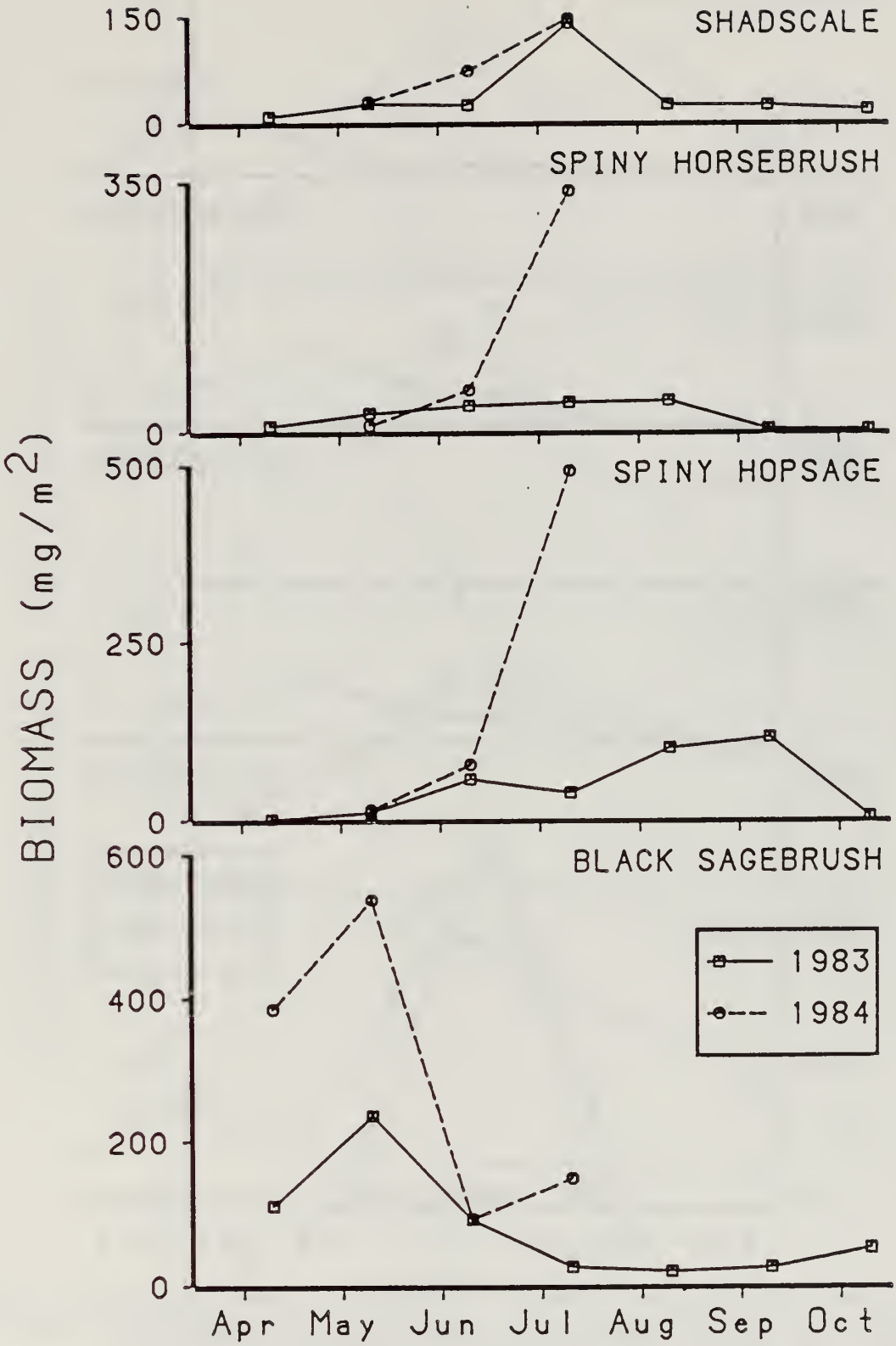

Fig. 5.4-5 Monthly changes in mean invertebrate biomass (mg/m^2 of shrub) of four host plants: black sagebrush, spiny hopsage, spiny horsebrush, and shadscale, 1983-1984. See Figs. 5.4-3. and 5.4-4 for sampling locations.

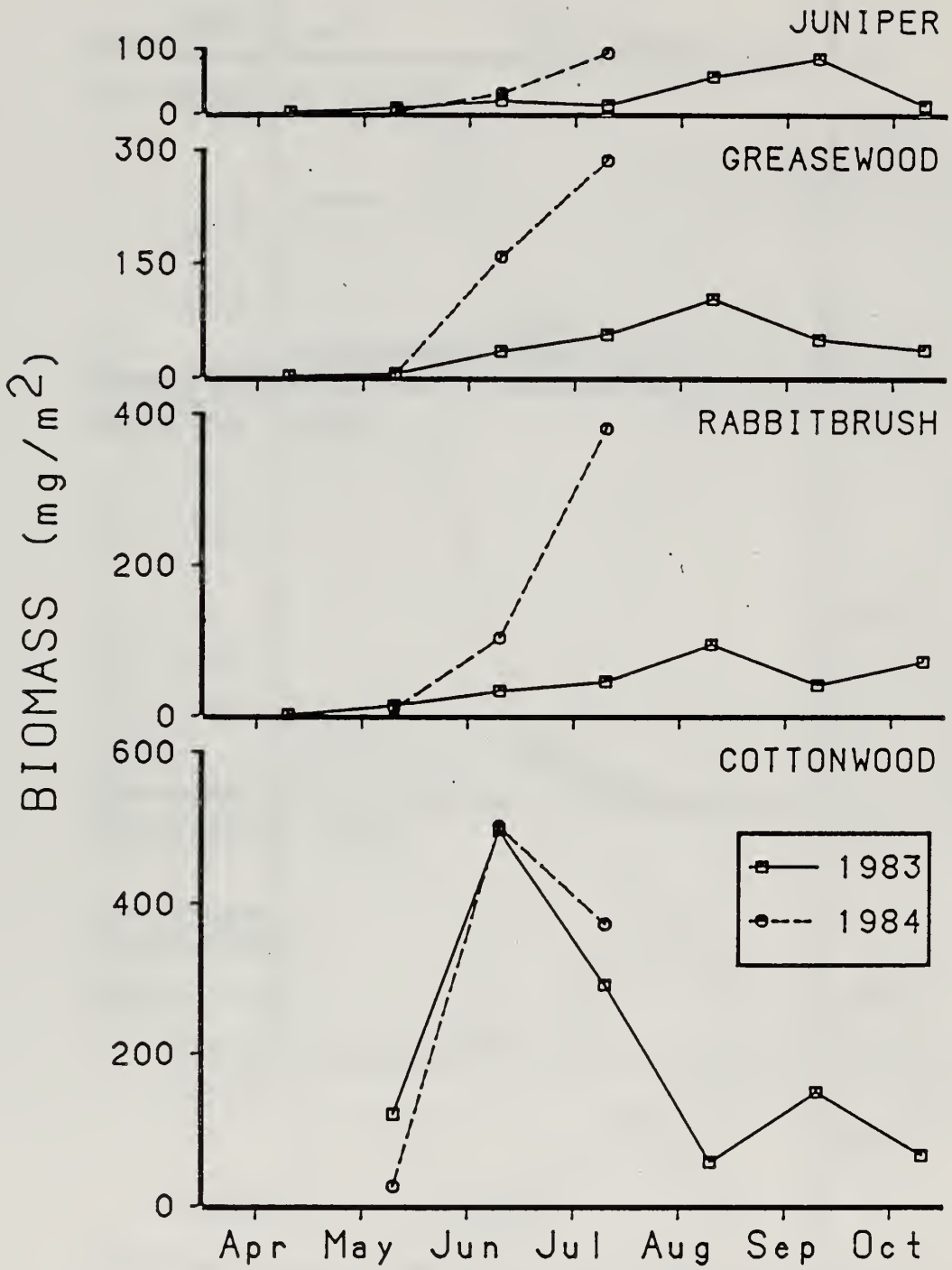

Fig. 5.4-6 Monthly changes in mean invertebrate biomass (mg/m^2 of shrub) of four host plants: cottonwood, rabbitbrush, greasewood and juniper, 1983-1984. See Figs. 5.4-3. and 5.4-4 for sampling locations.

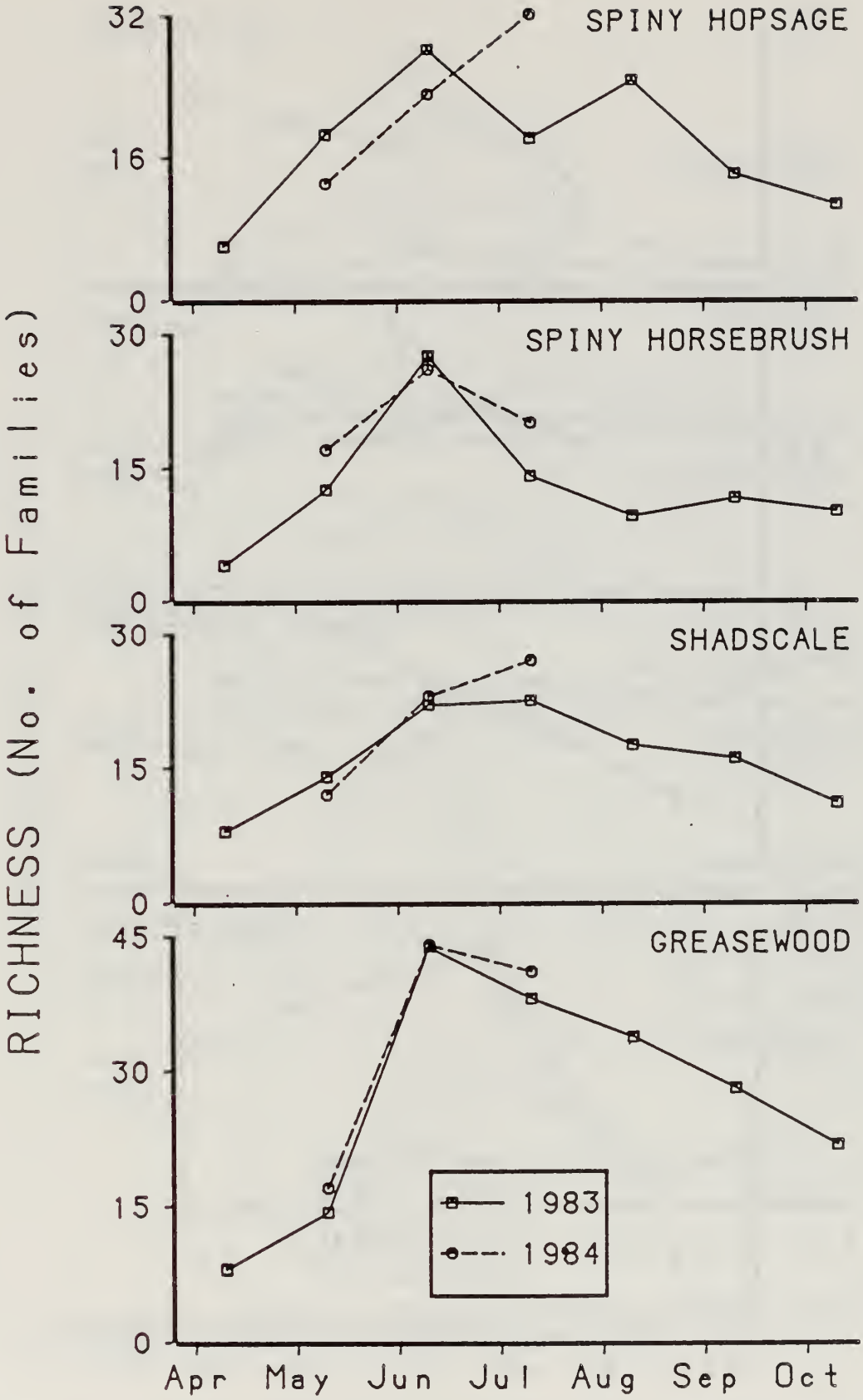

Fig. 5.4-7 Monthly changes in invertebrate richness (No. families/8 samples) on four host plants: greasewood, shadscale, spiny horsebrush and spiny hopsage, 1983-1984. See Fig. 5.4-3 for sampling locations.

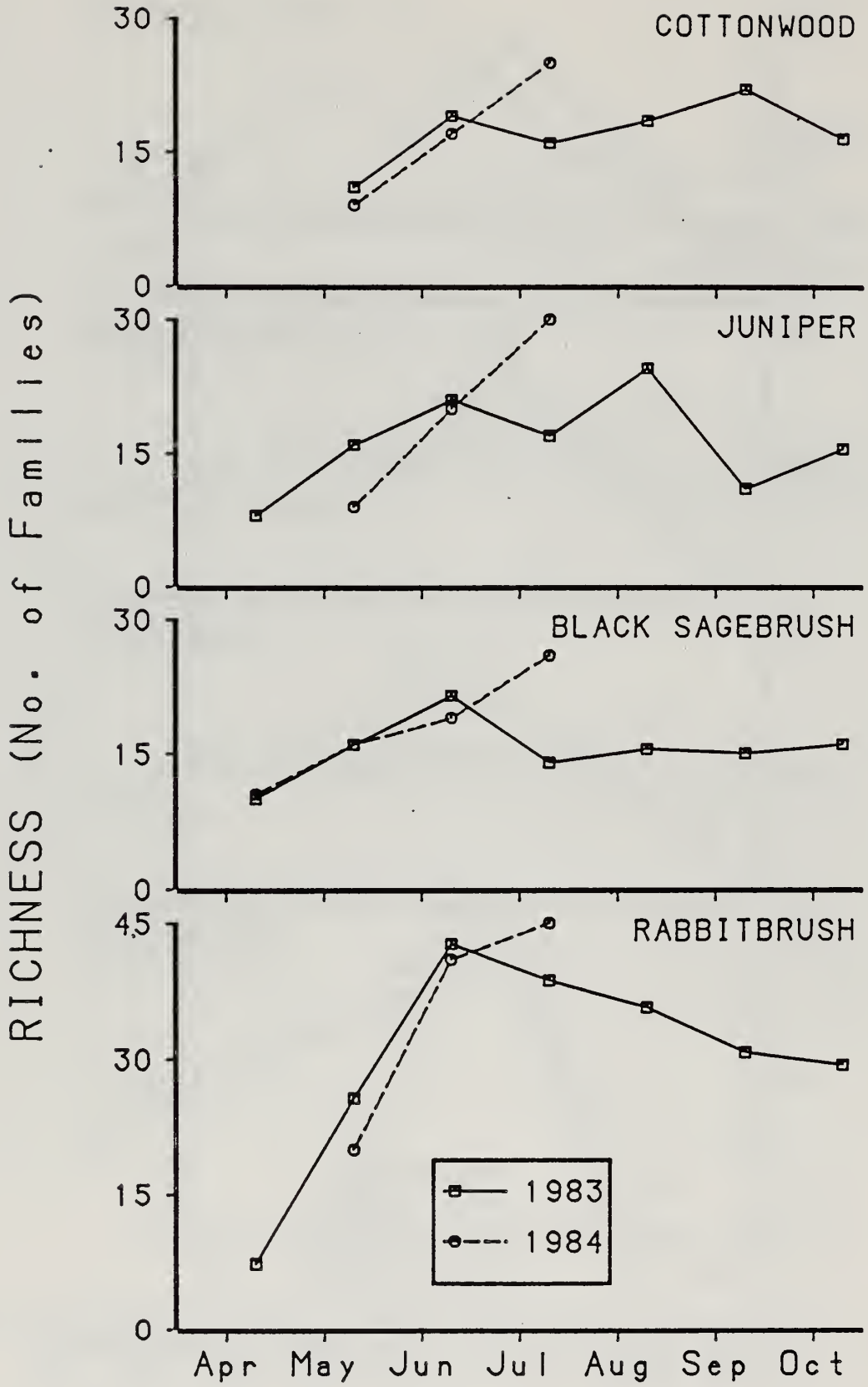

Fig. 5.4-8 Monthly changes in invertebrate richness (No. families/8 samples) on four host plants: rabbitbrush, black sagebrush, juniper and cottonwood, 1983-1984. See Fig. 5.4-4 for sampling locations.

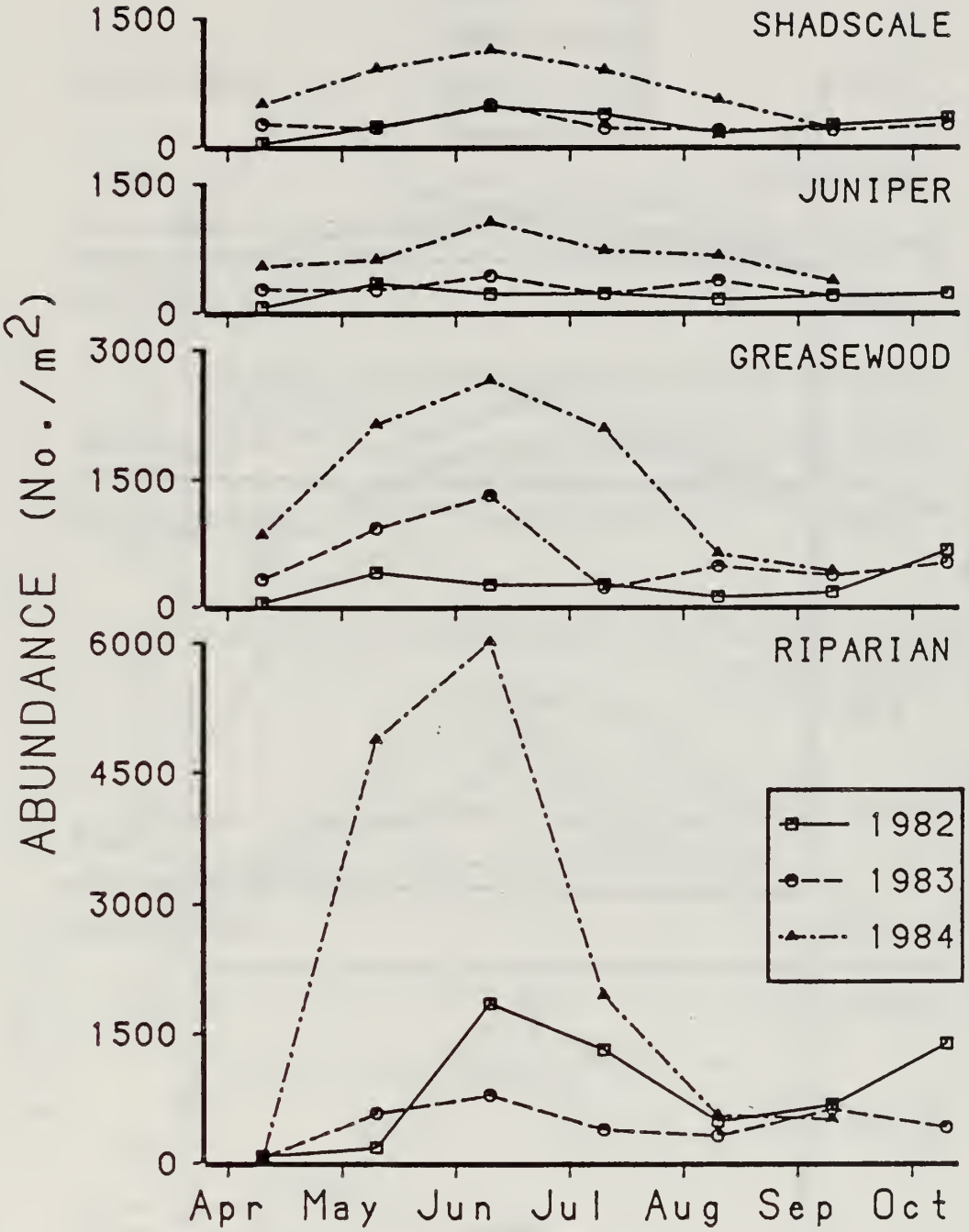

Fig. 5.4-9 Monthly changes in mean invertebrate abundance (No./m^2 of shrub) on big sagebrush in the 4 vegetation types, 1982-1984.

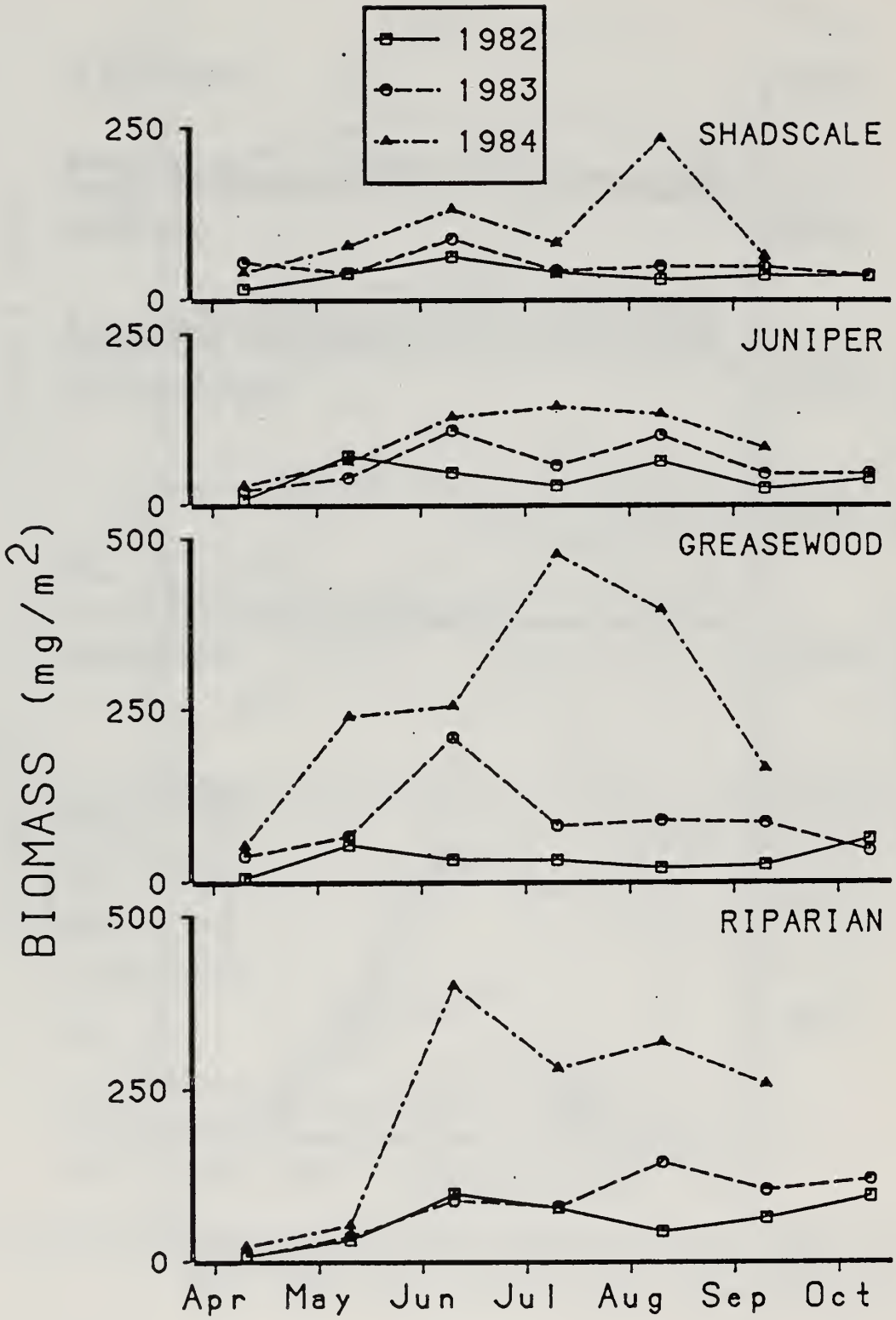

Fig. 5.4-10 Monthly changes in mean invertebrate biomass (mg/m^2 of shrub) on big sagebrush in the 4 vegetation types, 1982-1984.

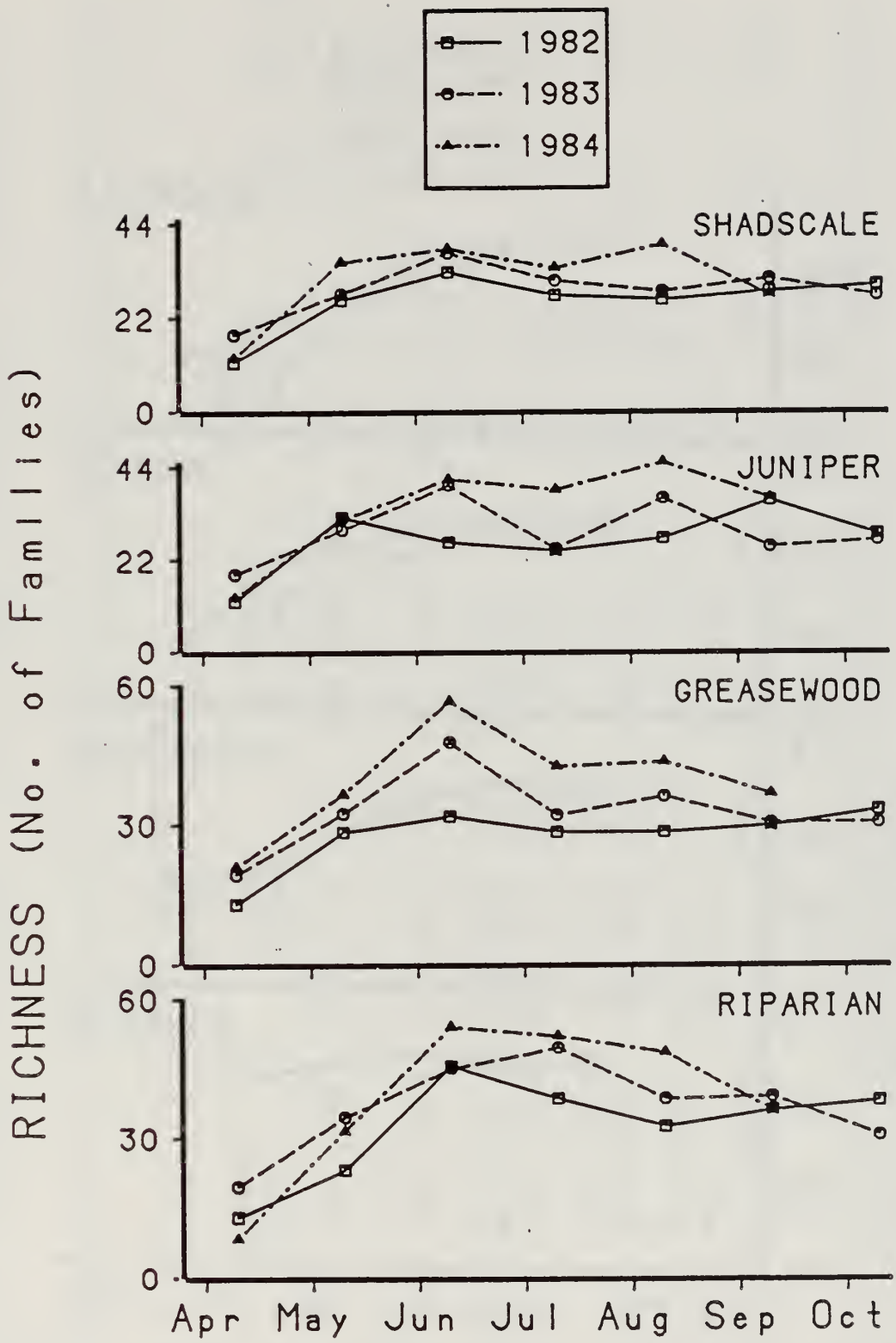

Fig. 5.4-11 Monthly changes in mean invertebrate richness (No. families./8 samples) on big sagebrush in the 4 vegetation types, 1982-1984.

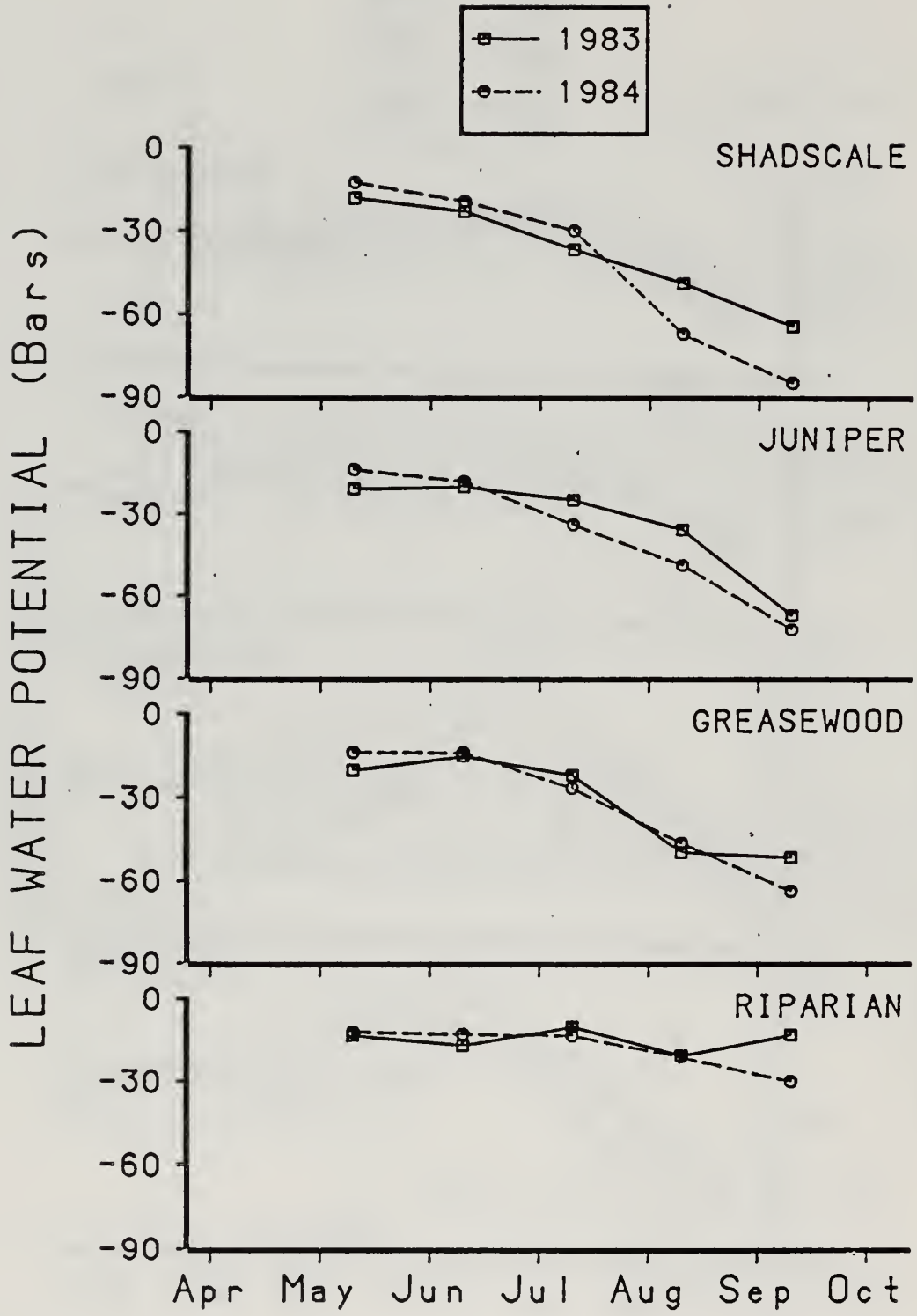

Fig. 5.4-12 Monthly changes in mean pre-dawn leaf water potential (bars) of big sagebrush in the 4 vegetation types, 1983-1984.

Table 5.4-3 Faunal characteristics of invertebrates on big sagebrush, and leaf water potential and slope of big sagebrush, 1982-1984. Also shown in total plant cover within 1 m^2 area around each big sagebrush shrub sampled (see Methods). Values are means for May-September, 8 samples/transect/month.

	Faunal Characteristics												
	Abundance (No/m^2)			Biomass (mg/m^2)			Richness (No. families)			Water Potential (Bars)**		Slope (%)	Total Plant cover (%)
Transect	1982	1983	1984	1982	1983	1984	1982	1983	1984	1983	1984	1984	1984
WG-1	160.0	388.9	2062.9	30.2	95.1	311.5	28.8	31.8	41.4	-33.8	-36.0	5.5	52.7
										(-17.6	-11.9)		
WG-2	282.1	342.1	---	39.4	63.3	---	28.0	34.0	---	28.9	---	---	---
WG-3	278.1	1244.7	1108.9	28.4	156.5	300.5	31.0	41.2	44.8	-29.0	-30.1	6.8	69.5
WJ-1	220.5	253.9	720.7	45.4	64.7	136.0	29.0	29.2	38.0	-33.6	-38.8	12.1	31.7
										(-12.7	-9.7)		
WJ-5	---	323.3	645.5	---	74.3	82.8	---	32.6	39.0	-33.4	-36.1	17.4	31.0
WS-1	322.8	259.52	827.3	39.9	60.5	127.3	27.6	31.6	33.6	-40.1	-41.8	18.9	34.3
										(-16.3	-16.3)		
WS-4	257.9	244.52	640.3	41.1	45.3	88.6	28.2	30.0	35.4	-37.8	-44.0	17.7	30.4
WR-4*	1118.1	540.9		68.7	88.4		35.8	39.4		-12.9			
WR-1*			2195.5			287.5			42.8		-17.2	4.6	88.9
WR-2	677.7	533.3	3358.2	55.3	90.0	233.8	34.4	43.2	46.0	-16.8	-18.9	6.4	56.8
										(-8.3	-9.1)		

*sampling site changed in 1984 from WR-4 to WR-1
**leaf water potential shown without parentheses; soil water potential in parentheses

August grasshopper densities (No./ha) in 1984 were estimated at 35000 in WG-1, 0 in WJ-2, 26000 in WS-1, and 30000 in WR-2, compared to 1983 densities of 17000 in WG-1, 1000 in WJ-1, 6000 in WS-1 and 7000 in WR-2. (Note the 1983 values in WRSOC (1984) are incorrect; those values should be divided by 2.)

5.4.1.4 Causal Mechanisms: Water and Topography. A major goal of the White River Environmental Monitoring Program has been to "guide analysis of cause and effect thus leading to appropriate mitigation planning" (WRSOC 1982). We have focused on 2 major factors which affect invertebrate abundance, biomass and richness, i.e., water (1983-1984) and topography (1984).

Those vegetation types with flatter slopes (Riparian and Greasewood), had greater leaf water potential of big sagebrush, greater total plant cover, and greater levels of abundance, biomass, and richness of invertebrate on big sagebrush (Table 5.4-3). Conversely, Juniper and Shadscale vegetation types had steeper slopes. This habitat characteristic was correlated with lower leaf water potential of big sagebrush, lower total plant cover, and lower invertebrate abundance, biomass and richness on big sagebrush. The mean values (according to transects, May-September) of these characteristics were fairly well-correlated (absolute value of r = 0.64 to 0.93; Table 5.4-4).

The topography-water-invertebrate relationship may be important to minesite rehabilitation. The slope of the spent shale pile will be an important factor in determining water stress to the plant, and water stress of the plant is a major factor in determining invertebrate faunal structure. Thus the physical structure of the pile will be an important determinant in the restructuring of invertebrate faunas.

Tables 5.4-5 lists the correlation between mean monthly leaf water potential and abundance of the most important foliage invertebrate groups shown in Table 5.4-1, according to transects. The groups which demonstrated

Table 5.4-4 Correlation coefficients (r) between foliage invertebrate faunal characteristics in 1984 and certain habitat conditions. The data are from Table 5.4-3. Significant (p 0.05) correlations are shown in bold face.

	Ground slope (%)	Total plant cover (%)	Leaf water Potential (Bars)
Abundance (No./m^2)	**-0.75**	0.61	**0.81**
Biomass (mg/m^2)	**-0.93**	**0.85**	0.64
Richness (No. families)	**-0.87**	**0.74**	**0.84**
Leaf Water Potential (Bars)	**-0.77**	**0.84**	--
Total Plant Cover (%)	**-0.84**	--	--

the strongest and most consistent positive relationship to leaf water potential of big sagebrush were the leafhoppers (Cicadellidae) and thrips (Thripidae), and to a lesser extent leaf beetles (Chrysomelidae) and leaf bugs (Miridae). These groups may consequently be used as "indicators" of habitats and shrubs that are less water-stressed.

Maintaining relatively unstressed plants may be one of the most important factors in preventing pest outbreaks. White (1984) has reviewed this subject, stating that natural and human-caused stress (e.g. pollution, etc.) to plants may lead to insect pest outbreaks. Preventing these outbreaks on revegetated areas will be crucial to the success of the revegetation.

5.4.2 Birds

Results of monitoring bird communities are divided into four sections: breeding birds, aquatic birds, raptors, and threatened and endangered species.

5.4.2.1 Breeding Birds. Seventy bird species were recorded on tracts Ua and Ub in June, 1984. More species were found in the forested habitats (i.e., 48 species recorded in Riparian and 33 species in Juniper than in Shrub habitats (i.e., 25 species in Shadscale and 24 species in Greasewood).

Species composition in all habitats was similar to that observed in June 1982 and 1983. One eastern kingbird (*Tyrannus tyrannus*) was seen in

Table 5.4-5 Correlations (r) between mean abundance (No./m^2) of the more important invertebrate taxa (see Table 5.4-1) and mean leaf water potential of big sagebrush along each transect in 1984. Number of samples per month was 8. Significant (p 0.05) correlations are shown in bold face.

	Monthly Correlations				
	May	Jun	Jul	Aug	Sep
Sap-Feeders					
Cicadellidae	0.23	0.51	0.35	0.42	**0.99**
Aphididae	-0.13	0.58	0.35	-0.13	0.57
Coccoidea	**-0.79**	-0.15	-0.50	-0.43	-0.52
Psyllidae	-0.15	0.20	0.27	*	*
Thripidae	0.42	0.50	**0.93**	0.49	**0.80**
Miridae	0.39	**0.75**	**0.87**	-0.33	0.51
Tetranychidae	0.45	0.11	-0.64	0.07	-0.36
Leaf-Chewers					
Curculionidae	0.19	-0.46	-0.38	-0.39	**-0.79**
Chrysomelidae	*	*	0.31	0.40	0.52
Lepidoptera	-0.04	-0.02	0.11	-0.07	-0.05
Acrididae	*	-0.03	-0.04	0.24	0.05
Diptera (Leaf-Miners)					
Agromyzidae	*	0.04	*	*	*
Saprophores					
Oribatidae	-0.61	0.68	-0.15	0.01	0.23
Sminthuridae	*	0.11	-0.31	-0.55	*
Liposcelidae	*	*	*	0.44	0.32
Omnivores					
Formicidae	0.01	-0.03	-0.01	0.17	0.28
Predators					
Araneida	0.03	0.32	-0.29	-0.34	-0.14

* taxon not abundant enough for analysis

Riparian habitat; the last time this species was seen in the study area was June 1976, also in Riparian habitat. A gray vireo (Vireo vicinior) was seen in Juniper habitat on 2 June 1984 This is the first record of the gray vireo in the Uinta Basin (Behle 1981). In Utah is it restricted to the southern and southeastern part of the state.

Avian consuming biomass was similar on the upland sites ranging from 264 g/20 ha in Juniper to 312 g/20 ha in Greasewood. In Riparian habitat, however, consuming biomass was nearly 10 times greater at 2438 g/20 ha (Table 5.4-6). Granivores comprised the largest portion of the breeding bird communities on the upland sites, whereas insectivores were the largest group in the Riparian habitat.

Consuming biomass (CB) of the breeding bird community (excluding raptors, aquatic birds, and air-cruising insectivores) either declined (Juniper and Riparian) or stayed the same (Greasewood and Shadscale) compared to the breeding bird communities studied in 1983 (Figs. 5.4-13 to 5.4-17). In all habitats except Riparian, CB of the breeding bird community fell within the 95% confidence limits seven-year baseline period. CB of the insectivore, omnivore, and granivore trophic groups changed markedly but in no discernible pattern (Figs. 5.4-18 to 5.4-19). Only ominivores in Greasewood, insectivores in Juniper, and insectivores in Riparian had CB outside the 7-year 95% confidence limits.

Among the insectivore foraging guilds, sharp declines in CB were observed in air hawkers in Riparian, Juniper, and Shadscale, foliage gleaners in Riparian, Juniper and Greasewood and bark probers in Riparian (Figs, 5.4-20

Table 5.4-6 Consuming biomass (g/20 ha) of avian trophic groups and guilds in June 1984 on the Utah Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild+	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	188.6	151.8	163.1	106.4
O	GGO	9.4	25.4	4.7	679.6
I		83.0	86.5	127.8	1647.6
	ACI	1.7	18.1	55.7	49.4
	AHI	3.2	23.0	2.1	67.9
	BGI	--	--	--	34.0
	BPI	--	--	--	4.5
	FGI	1.4	14.9	--	447.9
	GGI	76.7	30.4	70.0	1043.9
N	N	1.9	0.5	--	3.8
R	R	28.8	--	--	--
Total		311.7	264.2	295.6	2437.5

*G = Granivore; O = Omnivore; I = Insectivore.

+GGG = Ground-gleaning Granivore; GGO = Ground-gleaning Omnivore; ACI = Air-cruising Insectivore; AHI = Air-hawking Insectivore; BGI = Bark-gleaning Insectivore; BPI = Bark-probing Insectivore; FGI = Foliage-gleaning Insectivore; GGI = Ground-gleaning Insectivore; N = Nectarivore; R = Raptors (i.e., shrikes).

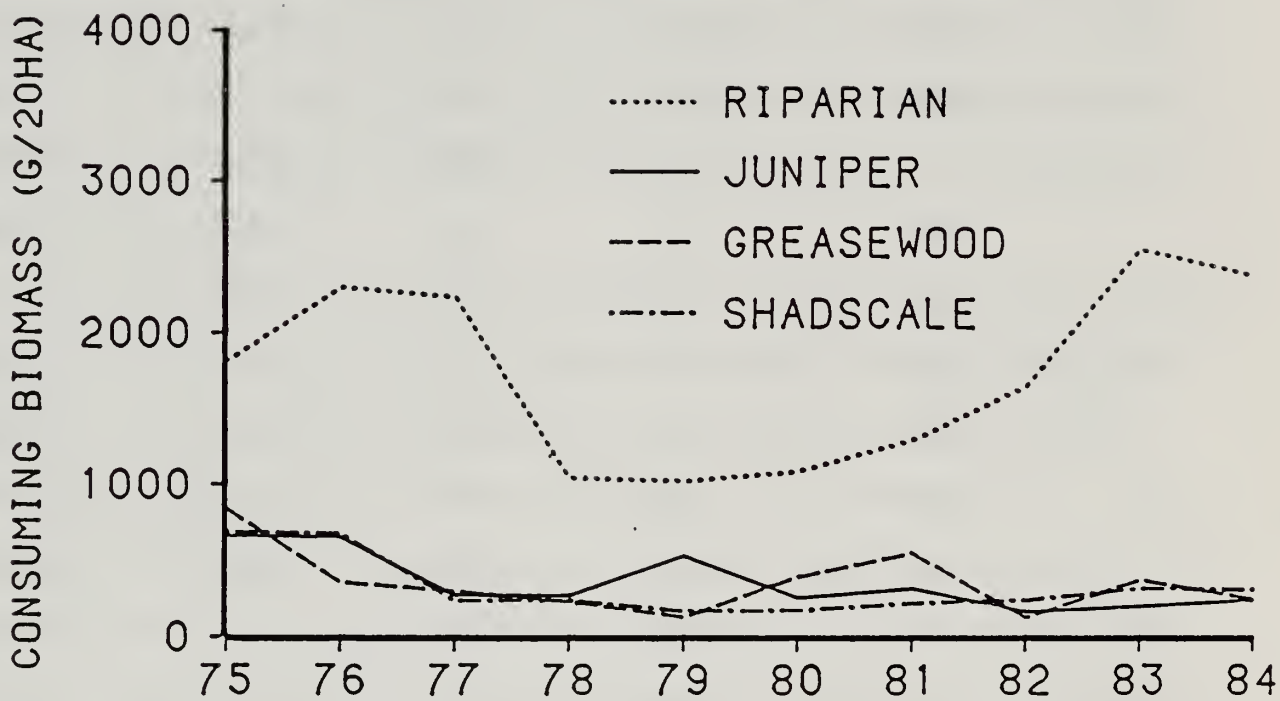

Fig. 5.4-13 Consuming biomass (g/20 ha) of the bird community in June from 1975 through 1984 in four habitats.

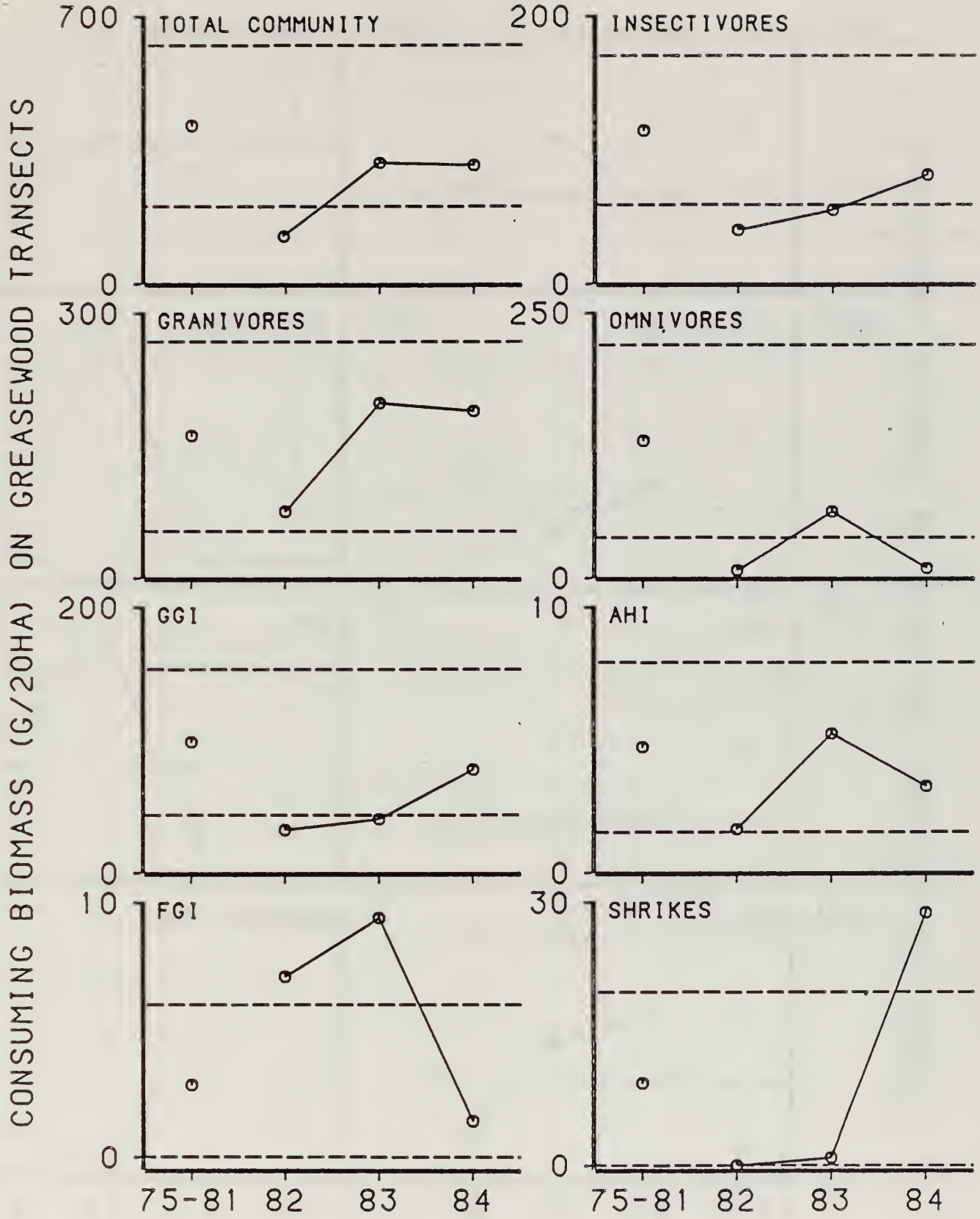

Fig. 5.4-14 Consuming biomass (g/20 ha) of the bird community, trophic groups, select insectivores guilds, and shrikes in Greasewood in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

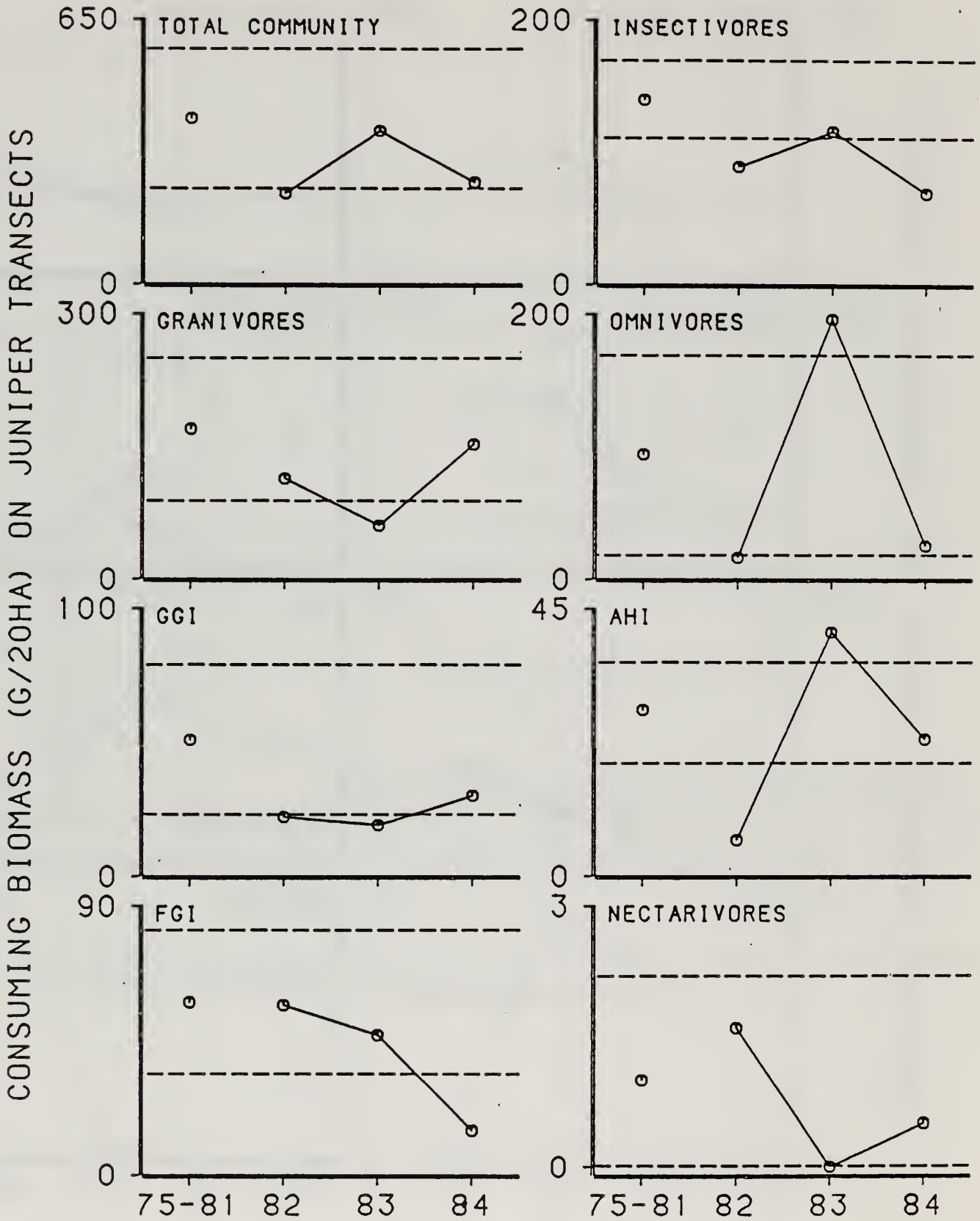

Fig. 5.4-15 Consuming biomass (g/20 ha) of the bird community, trophic groups, select insectivores guilds, and nectarivores in Juniper in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

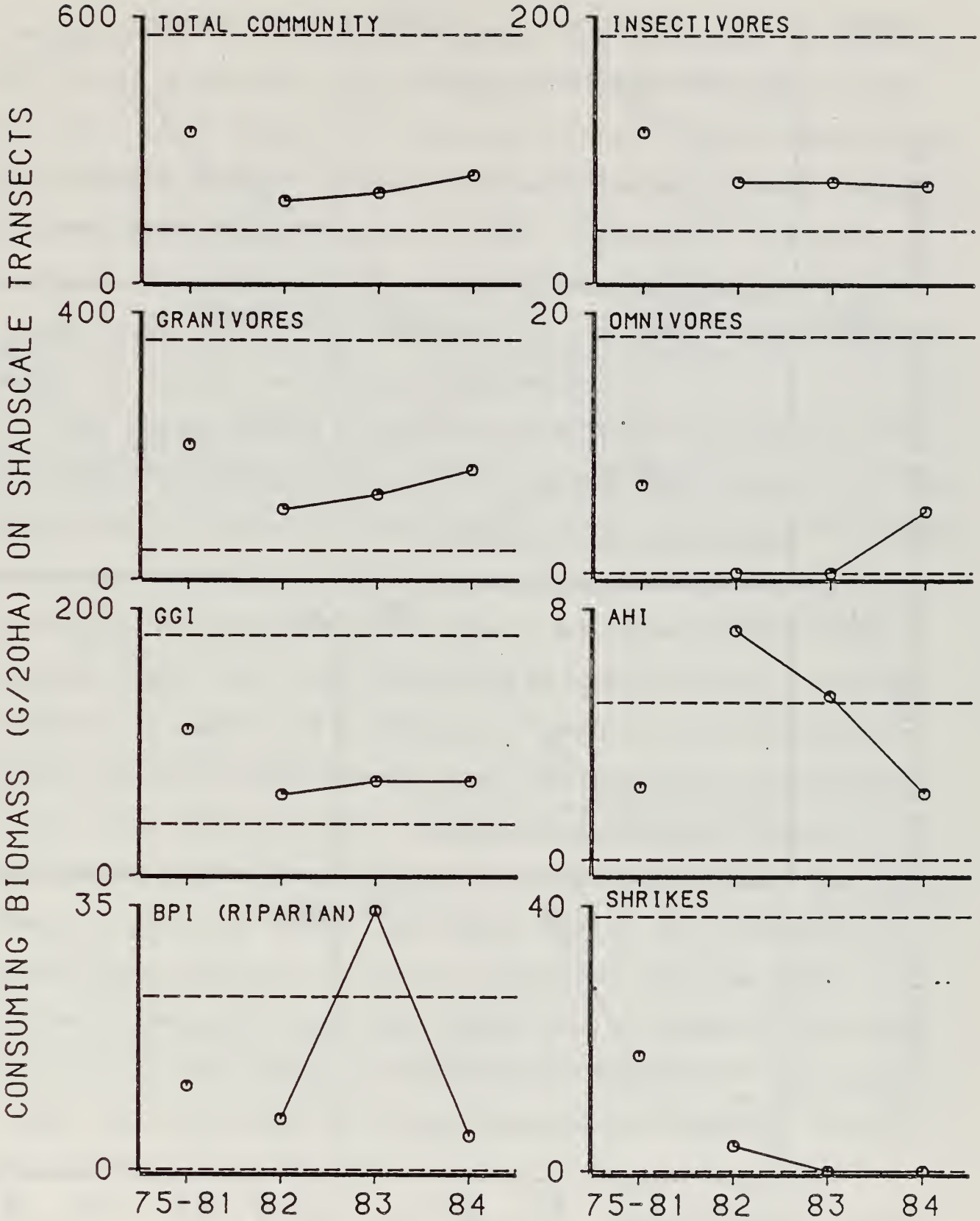

Fig. 5.4-16 Consuming biomass (g/20 ha) of the bird community, trophic groups, select insectivores guilds, and nectarivores in Shadscale and bark-probing insectivores in Riparian during June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

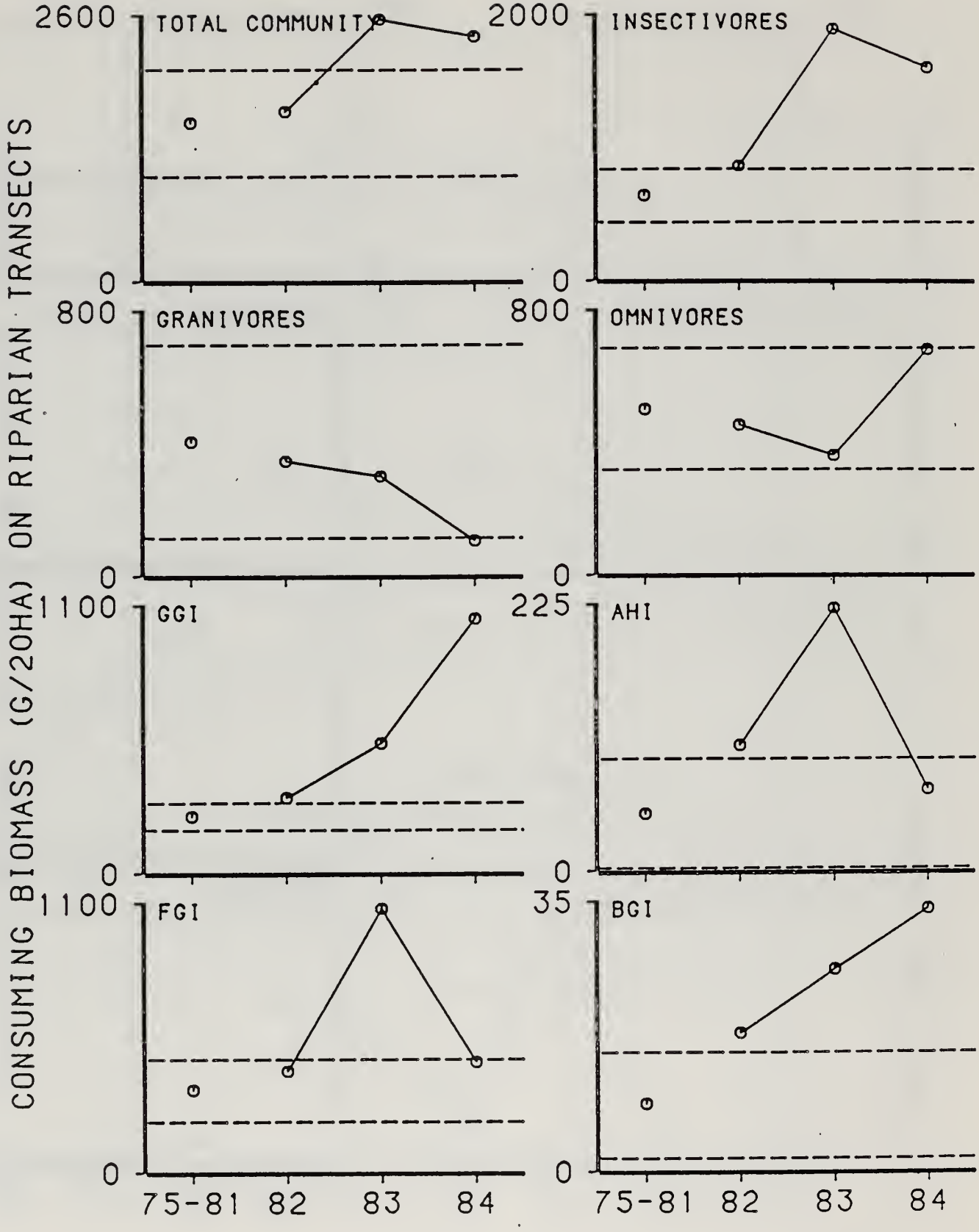

Fig. 5.4-17 Consuming biomass (g/20 ha) of the bird community, trophic groups, and select insectivores guilds in Riparian in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

through 5.4-21). Large increases were noted in ground gleaners in Riparian and shrikes in Greasewood. Air-cruising insectivores (which were excluded from Figs. 5.4-14 through 5.4-17 because they are difficult to census due to their constant movement) in Riparian decreased from approximately 1540 g/20 ha in 1983 to approximately 49 g/20 ha in 1984. Although CB of the total community changed only slightly in all habitats between 1983 and 1984, the trophic composition of those communities, i.e., the relative contributions of major trophic groups and guilds, changed markedly.

Bird species richness in Shadscale was 16, higher than the 7 year 95% confidence limits (Fig. 5.4-22); richnesses in all other habitats were within the confidence limits (Fig. 5.4-23 through 5.4-25). The increase in Shadscale was due to an increase in insectivores, primarily ground-gleaners. Species richness in the insectivore trophic group in Greasewood declined in 1984 compared to 1983 (Fig. 5.4-23), reflecting declines in richness of foliage gleaners, air hawkers, and air cruisers. Richness of foliage gleaners also dropped sharply in Juniper whereas other insectivore guilds have changed little since 1983 (Fig. 5.4-24). Richness of omnivores and granivores increased in Riparian while richness in insectivore guilds either decreased or stayed the same (Fig. 5.4-25). The changes noted in species richness of trophic groups and guilds confirms the conclusions drawn from changes in consuming biomasss that even though the community as a whole did not change markedly from 1983 to 1984, the distribution of species and biomass among trophic groups and guilds did change. This result is consistent with the results of the 7 year baseline study (WRSOC 1982): avian community characteristics vary markedly over time, that is, avian population dynamics, and the changes in community components (trophic groups and guilds) reflect trends that are not obvious at the community level.

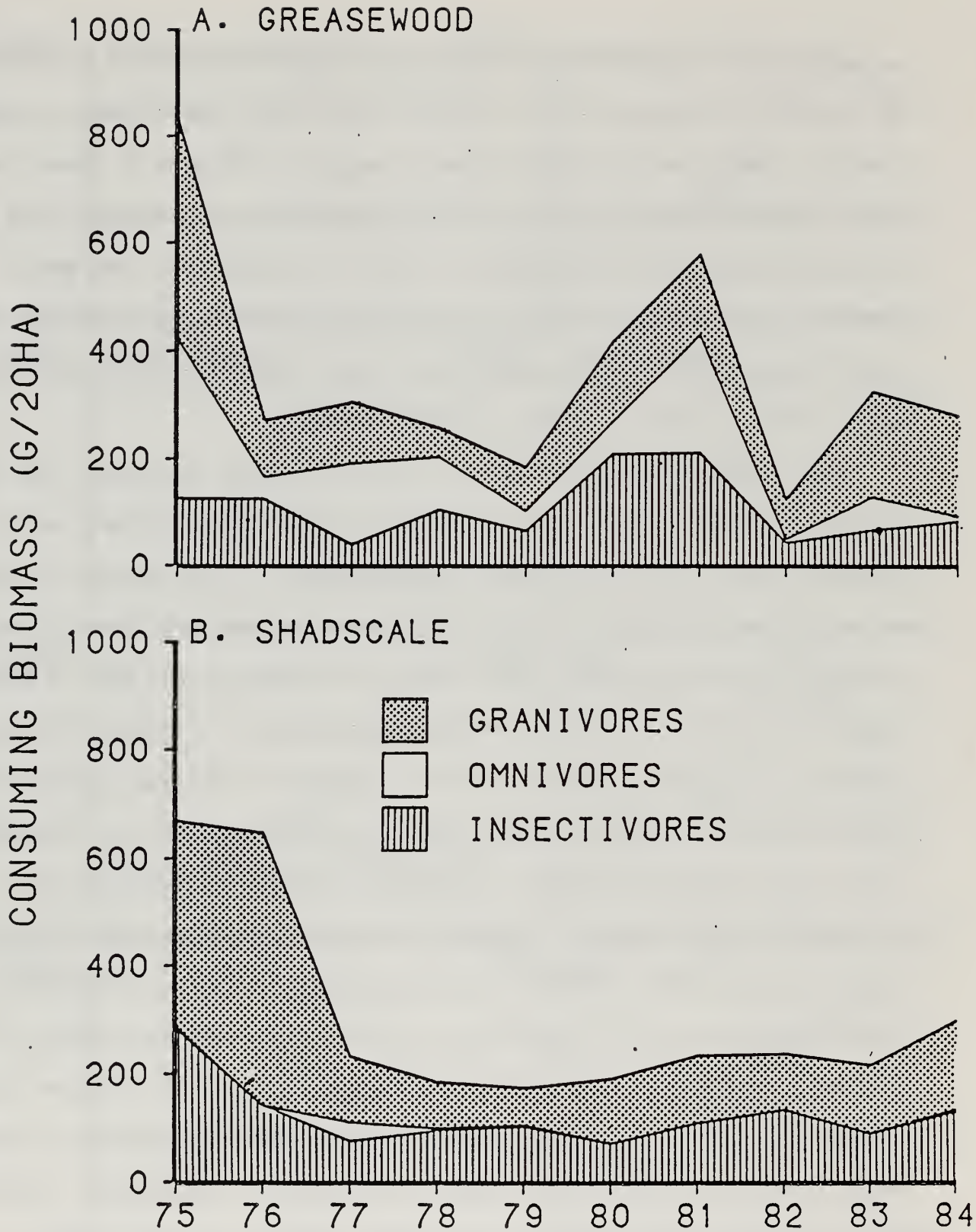

Fig. 5.4-18 Consuming biomass (g/20 ha) of three avian trophic groups in June from 1975 through 1984 in Greasewood and Shadscale.

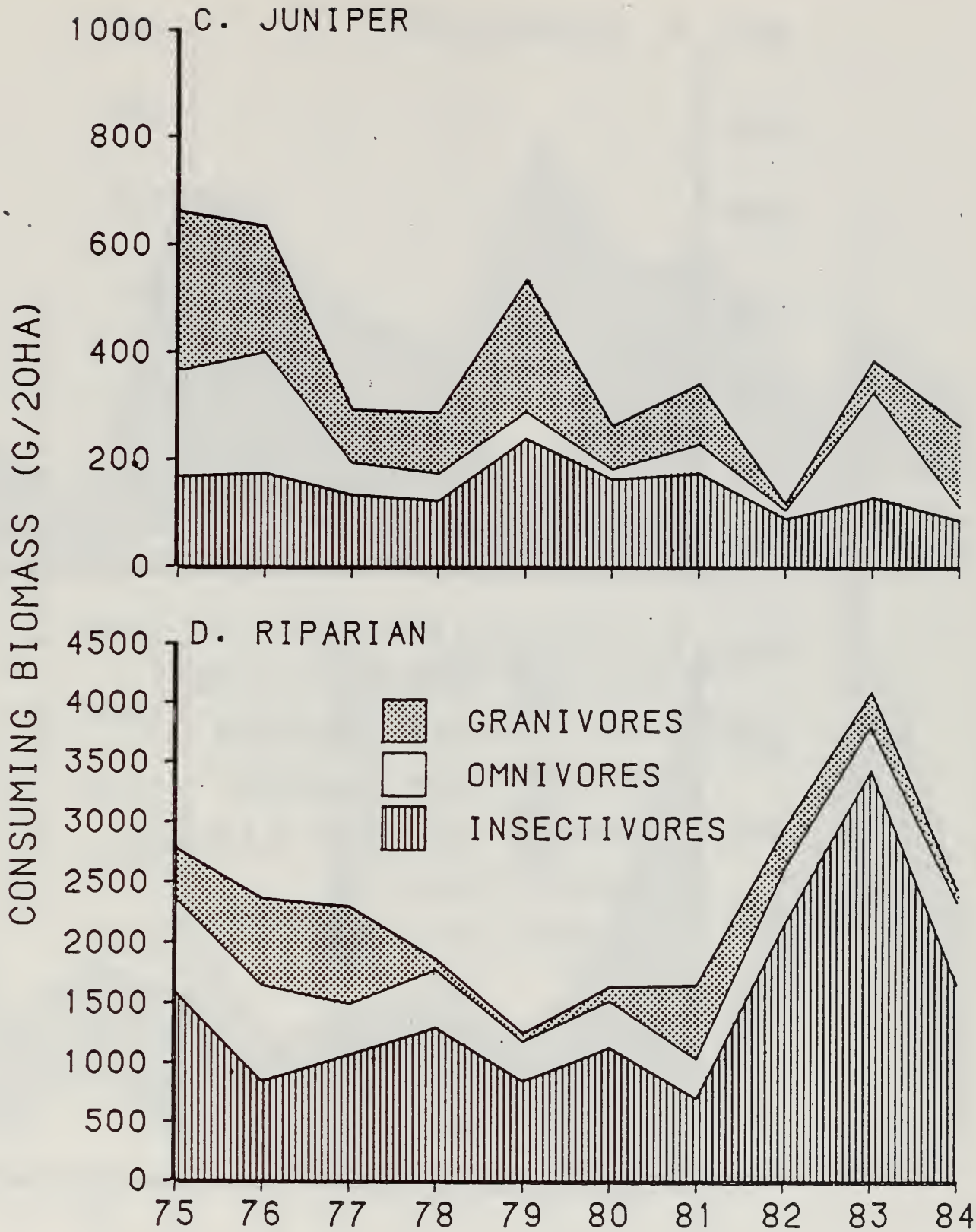

Fig. 5.4-19 Consuming biomass (g/20 ha) of three avian trophic groups in June from 1975 through 1984 in Juniper and Riparian.

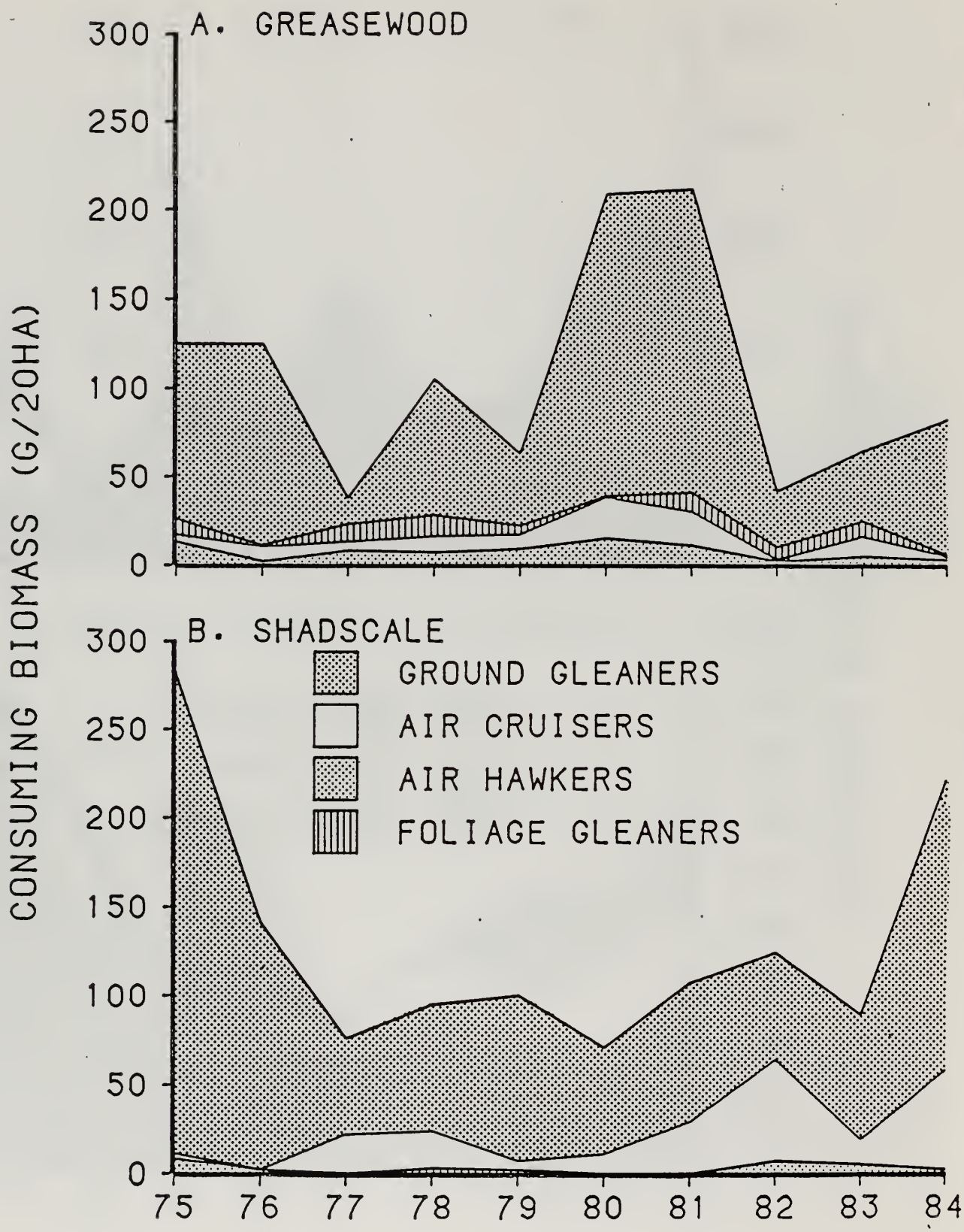

Fig. 5.4-20 Consuming biomass (g/20 ha) of insectivores guilds in June from 1975 through 1984 in Greasewood and Shadscale.

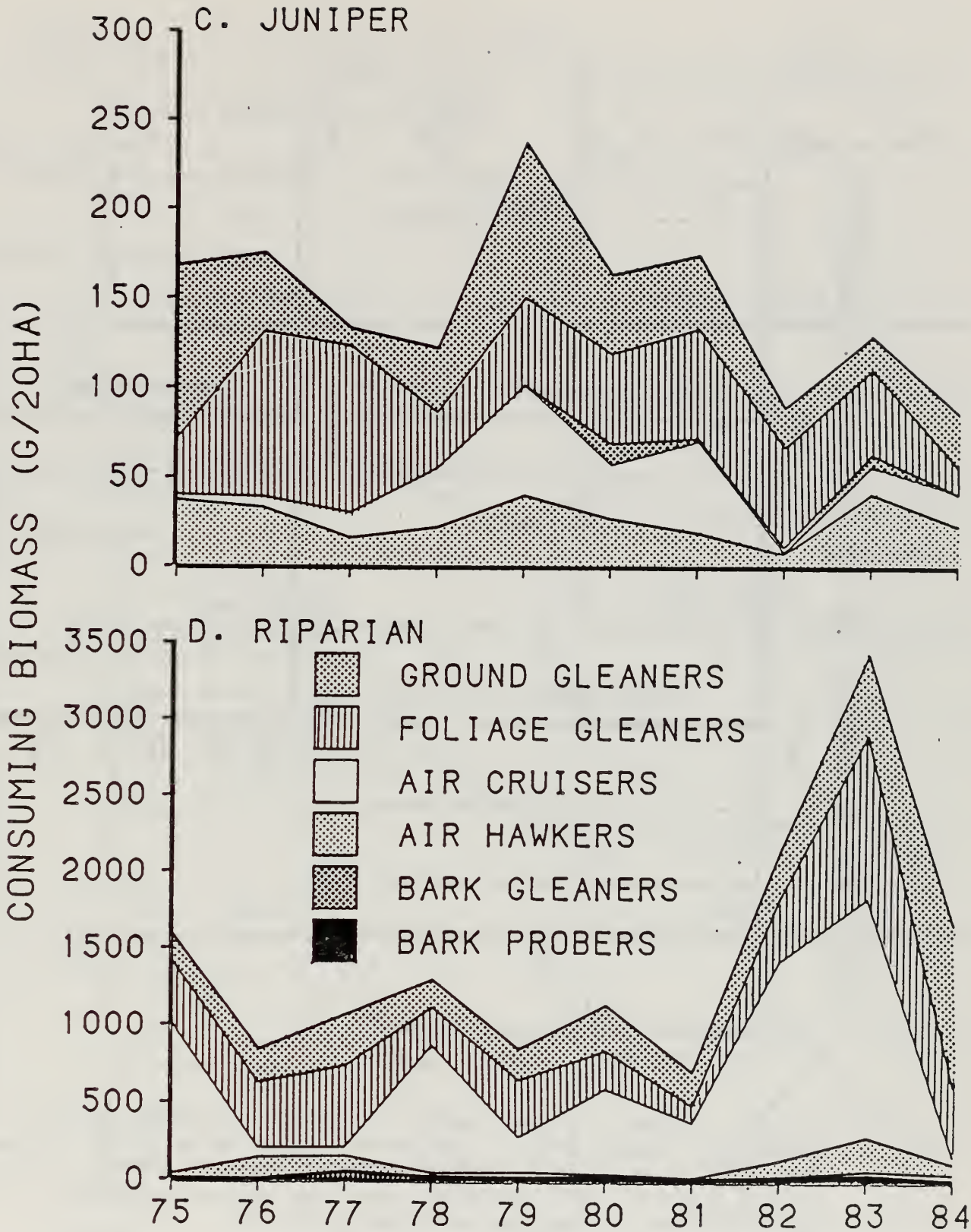

Fig. 5.4-21 Consuming biomass (g/20 ha) of insectivores guilds in June from 1975 through 1984 in Juniper and Riparian.

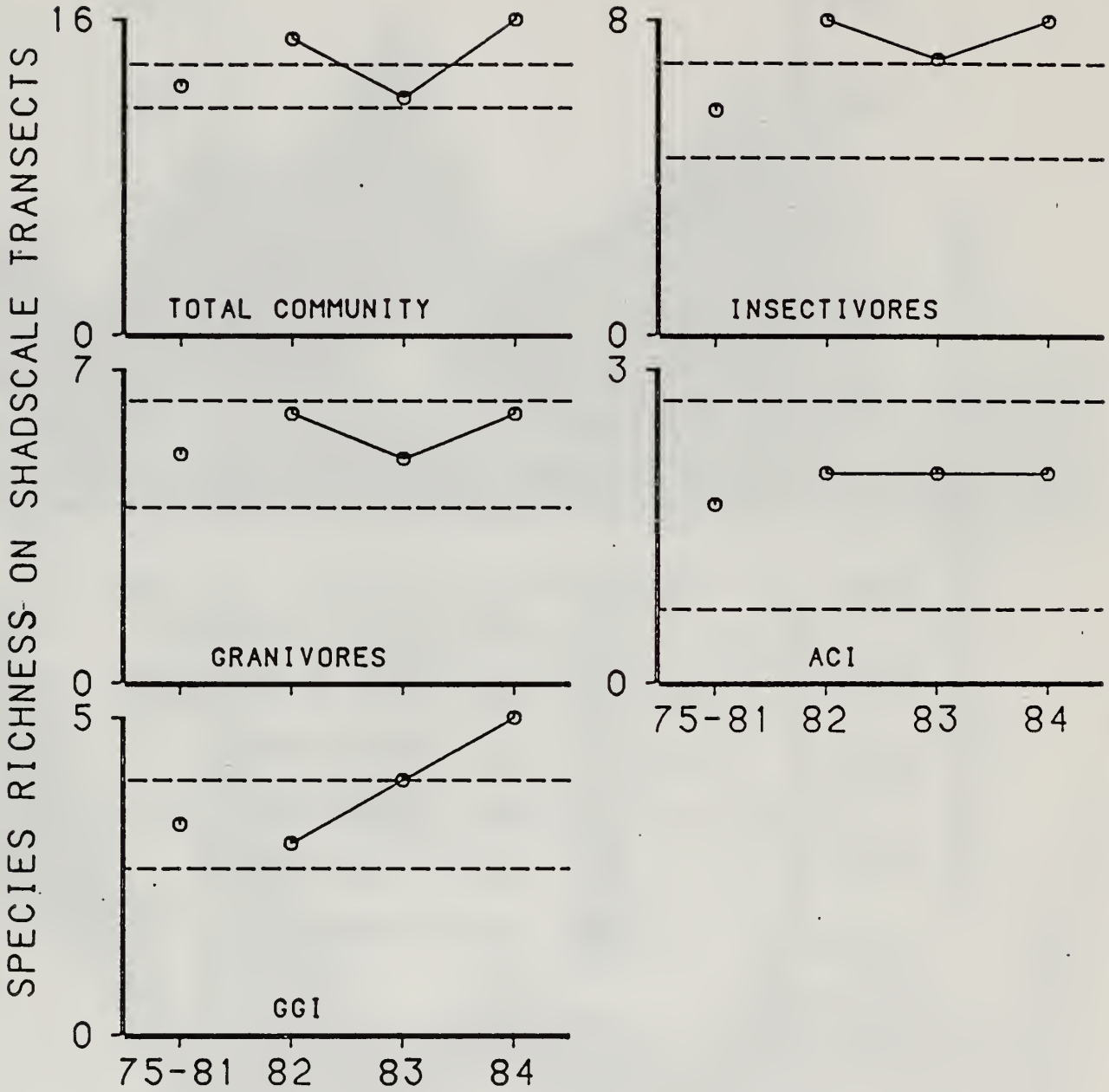

Fig. 5.4-22 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivores guilds in Shadscale in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

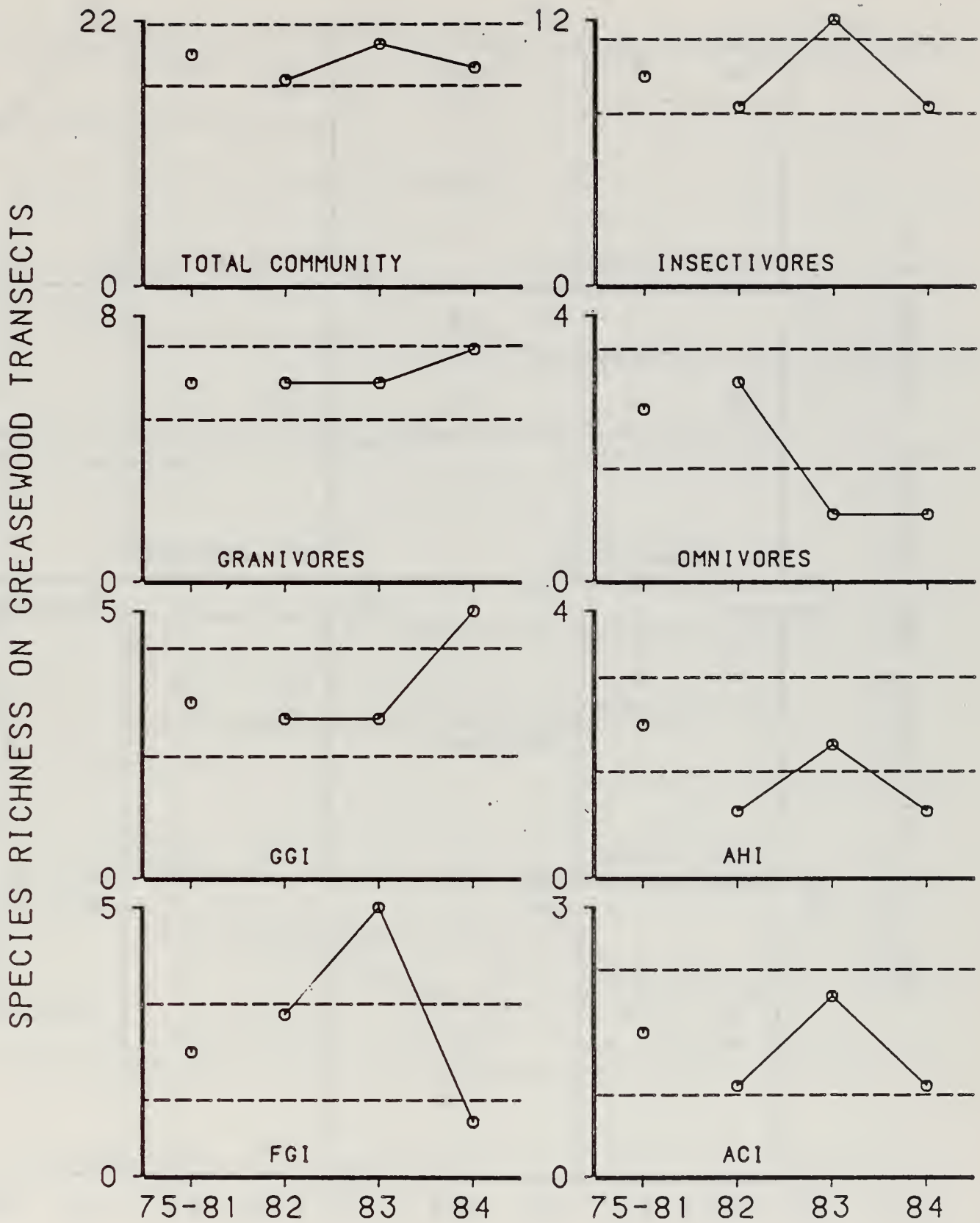

Fig. 5.4-23 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivores guilds in Greasewood in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

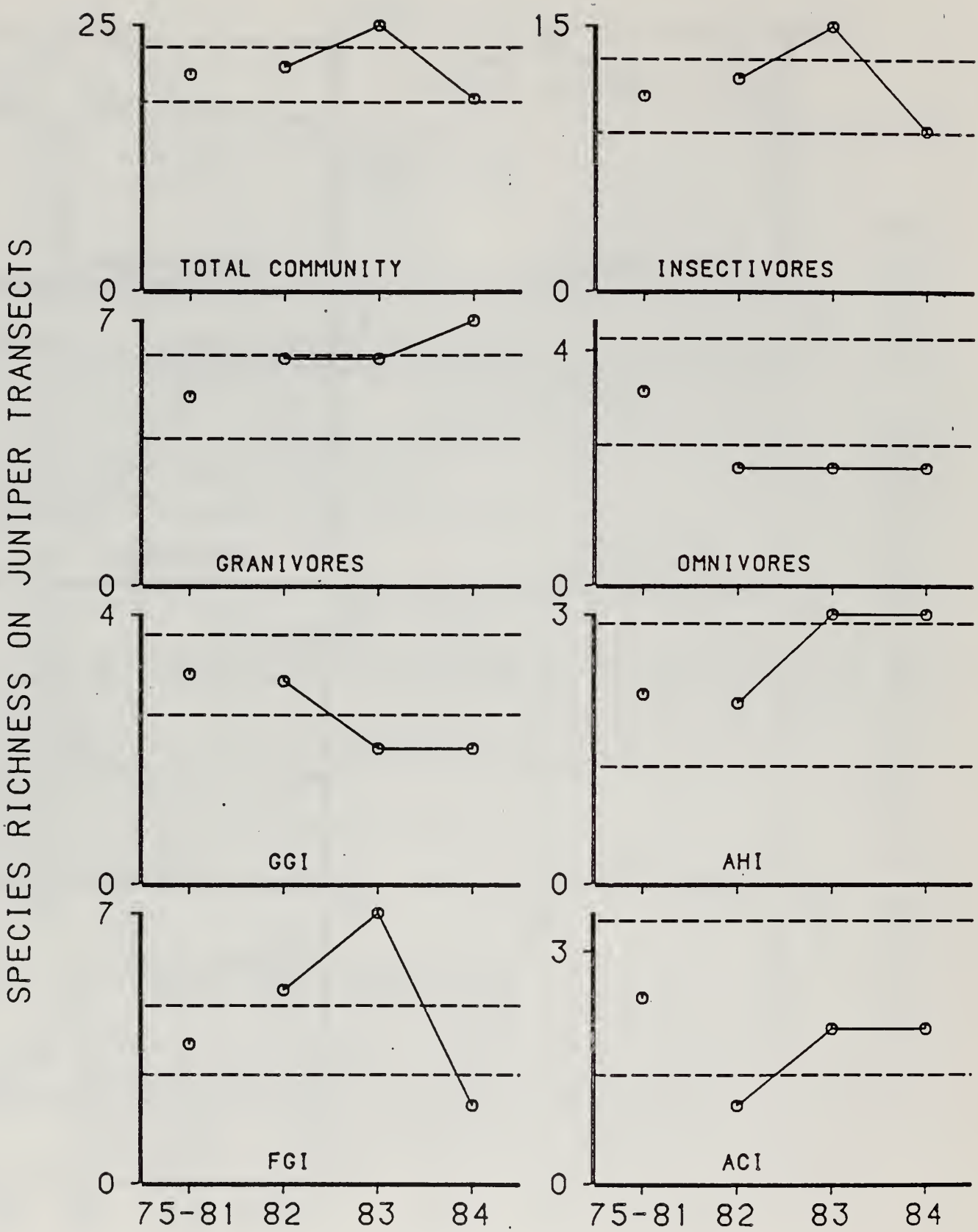

Fig. 5.4-24 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivores guilds in Juniper in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

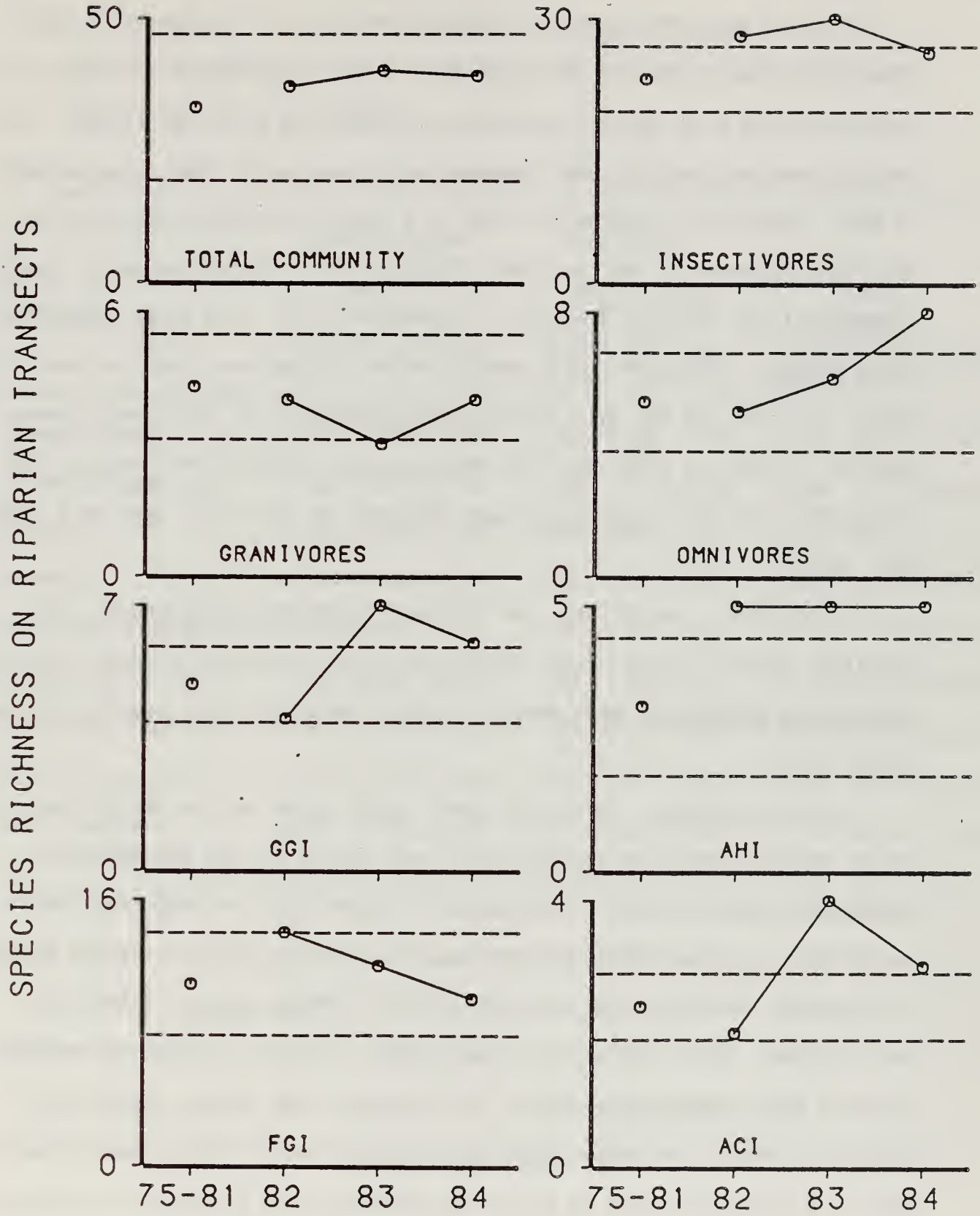

Fig. 5.4-25 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivores guilds in Riparian in June 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-7.

5.4.2.2 Waterfowl Survey. A waterfowl survey was conducted by canoe along a 32.8 km stretch of the White River from Cowboy Canyon to Asphalt Wash. Surveys were made on three consecutive days starting on 10 April 1984. Nine species were recorded in 1984, compared to 11 species in 1982, and 6 species in 1983. Waterfowl abundance in 1984 (2.1 individuals/river km) was lower than that recorded in 1982 and 1983 (Table 5.4-7). The Canada goose (*Branta canadensis*) was the same density as in 1982 and 1983. The green-winged teal (*Anas crecca*), the second most common species in 1982 and 1983, was much less common in 1984, and the mallard (*Anas platyrhynchos*, the third most common species in 1982 and 1983, was only recorded once (Table 5.4-7) during 1984. The northern pintail (*Anas acuta*) was recorded for the first time on a waterfowl survey.

In addition to waterfowl, one killdeer (*Charadrius vociferus*), 218 migrating sandhill cranes (Grus canadensis), and one black-crowned night heron (*Nycticorax nycticorax*) were seen. The night heron is a new species for the study tracts.

5.4.2.3 Raptors. During the April canoe survey of the White River, 23 golden eagles (*Aquila chrysaetos*) were seen during a 3-day period or 7.67 eagles/day (Table 5.4-8). This number is higher than the 1982 count (4.3 eagles/day) and lower than the 1983 count (10.7 eagles/day). Similar changes in abundance were noted in northern harriers (*Circus cyaneus*) (1982, 2.0 harriers/day; 1983, 16.7 harriers/day; 1984, 2.67 harriers/day) and American kestrels (*Falco sparverius*) (1982, 2.7 ind/day; 1983 ind/day; 1984, 5.0 ind/day). Red-tailed hawks (*Buteo jamacicensis*) were slightly more common in 1984 (8.0 hawks/day) than in 1983 (7.0 hawks/day) and four times as common as in 1982 (2.0 hawks/day). Turkey vultures (*Cathartes aura*) and Cooper's hawks (*Accipter cooperii*) were at low abundance and two winter residents, usually

Table 5.4-7 Waterfowl abundance (individuals/river km) along the White River from Cowboy Canyon to Asphalt Wash, 7-9 April 1982, 14-16 April 1983, and 10-12 April 1984.

Species	Cowboy Canyon to Dam Site (km 0-24.1)			Dam Site to Asphalt Wash (km 24.1-32.8)			Total Survey		
	1982	1983	1984	1982	1983	1984	1982	1983	1984
Canada Goose	1.88	1.86	1.56	1.23	0.34	1.65	1.71	1.46	1.59
Green-winged Teal	0.52	0.37	0.33	0.58	0.35	0.00	0.54	0.37	0.24
Mallard	0.36	0.25	0.01	0.42	0.29	0.00	0.38	0.25	0.01
Gadwall	0.19	0.19	0.03	0.00	0.04	0.00	0.14	0.15	0.02
American Wigeon	0.10	0.00	0.03	0.00	0.00	0.19	0.07	0.00	0.07
Lesser Scaup	0.08	0.00	0.00	0.04	0.00	0.00	0.07	0.00	0.00
Northern Shoveler	0.00	0.00	0.06	0.23	0.00	0.23	0.06	0.00	0.10
Blue-winged Teal	0.00	0.07	0.00	0.19	0.00	0.00	0.05	0.05	0.00
Red-breasted Merganser	0.07	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Common Merganser	0.04	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.01
Ring-necked duck	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Cinnamon Teal	0.00	0.00	0.03	0.11	0.00	0.08	0.03	0.00	0.04
Northern Pintail	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
All Waterfowl	3.24	2.78	2.07	2.80	1.02	2.15	3.13	2.31	2.10

Table 5.4-8 Raptor abundance (mean individuals/day) along the White River from Cowboy Canyon to Asphalt Wash on 10, 11, an 12 April 1984.

Species	Cowboy Canyon to Ignatio Bridge (km 0-7.1)	Ignatio Bridge to Dam Site (km 7.1-24.1)	Dam Site to Asphalt Wash (km 24.1-32.8)	Total Survey
Golden Eagle (Adults)	1.67	2.00	1.33	5.00
Golden Eagle (Juveniles)	2.00	0.67	0.00	2.67
Bald Eagle (Adults)	0.00	1.00	0.00	1.00
Red-tailed Hawk	4.33	3.33	0.33	8.00
Rough-legged Hawk	0.00	0.33	0.00	0.33
Cooper's Hawk	0.33	0.33	0.00	0.67
American Kestrel	1.67	2.33	1.00	5.00
Northern Harrier	2.67	0.00	0.00	2.67
Turkey Vulture	0.67	0.67	0.33	1.67
Total Abundance	13.34	10.66	2.99	27.01
Abundance/River km	1.90	0.63	0.34	0.82

absent by April, were present, bald eagle (Haliaeetus leucocephalus) and rough-legged hawk (Buteo lagopus) (Table 5.4-8).

Changes in April raptor populations determined along the canoe survey are, in general, similar to the changes in breeding raptor density observed tract-wide (see Table 5.4-11 below).

Table 5.4-8 indicates that raptors are more common in the upper portion of the surveyed area (Cowboy Canyon to Ignatio Bridge). This pattern in raptor abundance is probably due to two factors. First, the upper section of the surveyed area has more cliffs near the river where raptors roost at night. Second, raptors disperse from their roosts as the temperature rises in mid-morning. It is possible that many of the raptors that roost along the lower sections of the surveyed area had left the river area and were not counted during the census.

A preliminary raptor nest survey was conducted on 13-15 April to determine which of the 90 known raptor nests were active. On 1-4, 15-17 June, and 2 July, active nests were checked to determine breeding success. During the raptor survey, 20 new nests were found, raising the total to 110 nests on or within 3.2 km of tracts Ua and Ub. Condition of these nests is summarized in Table 5.4-9.

Thirteen active nests were located in 1984 (Table 5.4-10). Golden eagles (4 nests) and red-tailed hawks (6 nests) were the most common breeders. One breeding pair of prairie falcons (Falco mexicanus) and 2 breeding pairs of great horned owls (Bubo virginianus) were also located. Six of these nests were on tracts Ua and Ub: 4 red-tailed hawk nests, 1 golden eagle nest, and 1 great horned owl nest. The closest active nests to the plant site were Nest 14, a great horned owl nest about 0.5 km east of the security check station, and Nest 18, a golden eagle nest 1.6 km southeast of the administration

Table 5.4-9 Condition of 110 raptor nests located on or within 3.2 km of Utah Oil Shale Tracts, Ua and Ub, as of June 1984.

	Cliff Nests			Tree Nests		
Nest Type	Good-Fair	Poor	Obsolete	Good-Fair	Poor	Obsolete
Large stick	37	5	1	2		
Small stick	25	5	3	9		3
Prairie Falcon	6					
Great Horned Owl	12					
Long-eared Owl				1		1
Total	80	10	4	12	0	4

Table 5.4-10 Summary of raptor nestling productivity for 1984 for active nests on and near the Utah Oil Shale Tracts, Ua and Ub. Data from 1-4 and 15-17 June and 2 July 1984.

Species	Nest Number	Young Produced
Golden Eagle	18	2 young fledged, 1 downy chick dead in nest
	27	1 young near fledging
	44	2 young fledged
	54	1 young fledged
Red-tailed Hawk	13	2 young fledged
	61	2 young fledged
	69	2 young fledged
	81	1 young near fledging
	104	2 young fledged; 1 young dead in nest
	107	2 young fledged
Great Horned Owl	14	2 (or more) young fledged
	93	Success unknown
Prairie Falcon	108	4 young fledged

building. Both of these nests produced young (Table 5.4-10) and were unaffected by development activites.

The number of active eagle and red-tailed hawk nests in 1984 (10) was less than that recorded in 1983 (14) and more than that recorded in 1982 (6)(Table 5.4-11). However, these numbers are not directly comparable because the number of known suitable nest sites (i.e., large and small stick nests in good to fair condition) has changed over the three years: 1982, 37 nests; 1983, 58 nests; and 1984, 64 nests. Percent nest occupancy, a measure that partially corrects for the fact that more nest sites were known in the latter years of the study, was 16% in 1982, 24% in 1983, and 16% in 1984. There was a 50% reduction in the number of active golden eagle and red-tailed hawk nests between 1983 and 1984; the 1984 population was similar to 1982.

Reproductive success per pair of golden eagles decreased from 1.8 young fledged per active nests in 1983 to 1.5 young per active nest in 1984. For red-tailed hawks, reproductive success decreased from 2.1 young fledged per active nest in 1983 to 1.8 young per active nest in 1984. For both species, this is approximately 15% reduction in young produced per pair. This decrease was at least partially due to nestling mortality; one golden eagle chick (Nest 27) and one red-tailed hawk young (Nest 104) were known to have died in the nest. Another possible cause for reduced production in 1984 may have been smaller mean clutch size.

A third difference in raptor breeding between 1983 and 1984 was later fledging dates in 1984. In 1983 most young fledged in mid June whereas in 1984 fledging occurred from mid June through the first week of August.

The decline in raptor productivity from 1983 to 1984 is probably due to the reduced desert cottontail population (see Section 5.4.3.2 Desert Cottontails and Black-tailed Jackrabbits). The cottontail population density in June 1984 was only about 2% of the 1983 population. Although cottontail

Table 5.4-11 Number of active raptor nests in the vicinity of the Utah Oil Shale Tracts, Ua and Ub, in 1982, 1983, and 1984.

Species	1982	1983	1984
Golden Eagle	3	7	4
Red-tailed Hawk	3	7	6
Cooper's Hawk	1	1	0
Prairie Falcon	1	1	1
Great Horned Owl	3	3	2
Long-eared Owl	1	1	0
Raven	0	0	0
Turkey Vulture	0	0	0
Total	12	20	13

remains were seen in several nests, raptors probably had difficulty obtaining cottontails, which were their primary prey in 1982 and 1983. A relationship between prey density and reproductive success has been documented for raptors (Bechard 1983, Edwards and Collopy 1983, Tjernberg 1983). Low prey density may also have caused the later fledging dates by delaying the initiation of egg laying and by slowing growth rates. The cold snowy spring of 1984 may also have resulted in delayed initiation of breeding. A decline in vole populations (see Section 5.4.3.1 Rodents) may account for the decline in northern harrier and American kestrel abundance during April.

5.4.2.4 Threatened and Endangered Species. The White River was surveyed by helicopter on 22 February 1984 for bald eagles and other wintering raptors. A total of 22 bald eagles as seen on the survey route (plus 10 seen off the survey route) in 1984 compared to 16 (plus 10 off the survey route) in 1983 and 10 (none off survey route) in 1982 (Table 5.4-12). As in 1982 and 1983, the section of river with the highest bald eagle population was that between Ignatio Bridge and Cowboy Canyon. Nearly all the bald eagles seen off the survey route were seen between Cowboy Canyon and the Colorado State Line. Juvenile bald eagles comprised 23% of the local population in 1984 compared to 30% in 1983 and zero percent in 1982. These data indicate that the bald eagle population wintering along this section of the White River has increased dramaticaly over the last three years but the increase was restricted to a short section of the river (approximately 11 km) between Cowboy Canyon and Ignatio Bridge (Table 5.4-12).

During the helicopter survey, 10 golden eagles, 7 northern harriers, 4 red-tailed hawks, and one prairie falcon were sighted.

During the April waterfowl survey (10-12 April), one (and possibly a second) adult bald eagle was seen along the White River between Ignatio Bridge

Table 5.4-12 Results of bald eagle surveys along the White River in winter (February) from 1982 to 1984.

Year	Cowboy Canyon to Ignatio		Ignatio to WR Dame Site		WR Dam Site to Asphalt Wash		Total on Survey Route		Off the Survey Route	
	Ad	Imm	Ad	Imm	Ad	Imm	Ad	Imm	Ad	Imm
1982	6	0	1	0	3	0	10	0	0	0
1983	7	4	2	1	2	0	11	5	6	4
1984	16	5	0	0	1	0	17	5	9	1

and Asphalt Wash (Table 5.4-8).

5.4.3 Mammals

Twenty-seven species of mammals were seen on tracts Ua-Ub during 1984 including 4 domesticated species: cattle (*Bos taurus*), sheep (*Ovis aries*), horse (*Equus caballus*), and dog (*Canis domesticus*). Five species of carnivores were recorded: striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and ringtail cat (*Bassariscus astutus*). The ringtail cat, which was found dead along a road, is the first verified record on tracts Ua-Ub. The individual found at tracts Ua-Ub was in juniper woodland adjacent to numerous small canyons through the Uinta Formation about 2 km east of the plant site. Habitat of the ringtail cat varies and includes canyons, wooded areas, or rocky terrain in the southwestern U.S. extending as far north as northern Utah.

Further discussion of mammals is divided into three sections: 1) rodents (data from trapping grids), 2) desert cottontails and black-tailed jackrabbits (data from flushing transects), and 3) big game (data from opportunistic sightings and flushing transects).

5.4.3.1 Rodents. Rodent trapping was conducted on four grids in August 1984: WG-1, WJ-1, WR-2, and WS-1. The objective of this section is to compare the structure of the rodent community on each grid in 1984 with that in 1982, 1983 and the baseline period. Factors that may have caused changes in community structure are discussed.

Rodent density (ind/ha), species richness (number of species), and diversity (H') on Greasewood (WG-1) were within the 7-year 95% confidence limits (Fig. 5.4-26). Rodent density was lower than the 7-year mean, although it was similar to 1983 in density. Richness and diversity were both higher in 1982 and 1984 than in 1983. The low values in richness and diversity in 1983 were due to the fact that three species, white-tailed antelope squirrel

(Ammospermophilus leucurus), pinon mouse (Peromyscus truei), and canyon mouse (Peromyscus crinitus), that were present on the trapping grids in 1982 and 1983, were absent in 1984 (Table 5.4-13). A decline in Ords' kangaroo rat (Dipodomys ordii) abundance on Greasewood in 1984 compared to 1982 contributed to the lower density and species diversity in 1984.

Rodent density, species richness, and species diversity in Juniper (WJ-1) declined markedly from 1982 to 1984 but only species diversity fell below the 7-year 95% confidence limits in 1984 (Fig. 5.4-26). These declines reflect the absence of five species, white-tailed antelope squirrel, desert wood rat (Neotoma lepida), bushy-tailed woodrat (Neotoma cinerea), pinon mouse, and canyon mouse, that were fairly common on WJ-1 in 1983 (Table 5.4-13). These five species contributed 54% and 53% of the density in 1982 and 1983, respectively. In addition, only one least chipmunk (Eutamius minimus) and one Apache pocket mouse (Perognathus apache) were trapped in 1984 compared to five each in 1982.

Rodent density in Shadscale (WS-1) increased dramatically in 1984 even though species richness and species diversity have changed little since 1982 (Fig. 5.4-26). The increased density was largely due to two species: the deer mouse (Peromyscus maniculatus) which nearly doubled in density, and the western harvest mouse (Reithrodontomys megalotis), which was absent in 1982 and uncommon in 1983, became the second most abundant species, making up 34% of the total rodent density (Table 5.4-13). Heteromyid rodents (i.e., Ord's kangaroo rat, and Apache pocket mouse) on the other hand, declined in density from 1982 to 1984. Montane voles (Microtus montanus) were recorded on WS-1 for the first time since trapping began in 1975.

Density, species richness, and species diversity have all decreased significantly since 1982 in Riparian (WR-2) (Fig. 5.4-27). Since no baseline

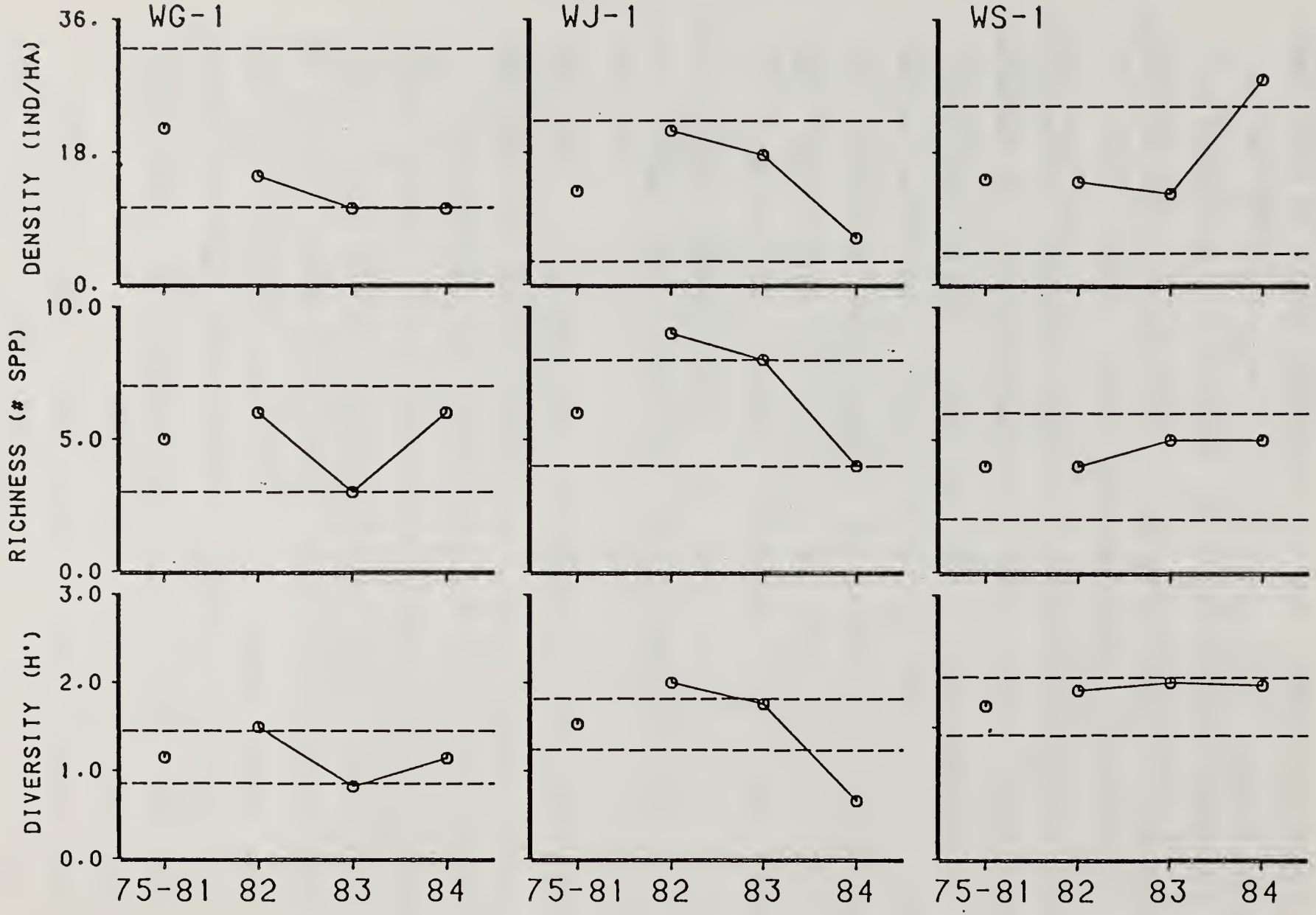

Fig. 5.4-26 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Greasewood (WG-1), Juniper (WJ-1), and Shadscale (WS-1) in August 1982 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981).

Table 5.4-13 Number of rodents captured on grids WG-1, WJ-1, WS-1, and WR-2 during August of 1982, 1983, and 1984.

	Greasewood			Juniper			Shadscale			Riparian		
Species	1982	1983	1984	1982	1983	1984	1982	1983	1984	1982	1983	1984
White-tailed Antelope Squirrel	5	0	1	3	3	0	4	1	0			
Least Chipmunk				5	1	1						
Desert Woodrat				8	5	0						
Bushy-tailed Woodrat				4	3	0				17	0	0
Deer Mouse	11	15	18	15	19	14	13	18	32	54	102	49
Pinon Mouse	1	0	1	10	9	0						
Canyon Mouse				6	5	0						
Western Harvest Mouse	1	0	5	0	0	1	0	4	26	0	14	4
Mountain Vole							0	0	4	59	36	0
Ord's Kangaroo Rat	14	12	1	1	0	0	17	13	6	3	6	0
Apache Pocket Mouse	8	1	2	5	2	1	18	10	8			
TOTALS	40	28	28	57	47	17	52	46	76	133	158	53

data are available for WR-2, the 7-year 95% confidence limits and means for WR-1 are plotted in Fig. 5.4-27 for comparison. Only two species were trapped in 1984: the deer mouse and western harvest mouse (Table 5.4-13). Deer mice accounted for 92% of the rodent density. Montane voles, which were first recorded on tracts Ua-Ub in 1981, were abundant in 1982 and 1983 but none were trapped in 1984. However, a few montane voles were seen during opportunistic surveys in riparian habitat. Bushy-tailed woodrats, which were common in 1982 and 1983, were also not trapped in 1984. Thus, the rodent community on WR-2, which in the past was comprised of 4 or 5 species, is now comprised of 2 species and is dominated by deer mice.

Rodent communities in each of the four vegetation types on Ua-Ub changed markedly during the baseline period (1975-1981; WRSOC 1982). Considerable variation in rodent community structure has also occurred during the development phase of the WRSOC project, however, effects of development cannot be traced to any of the changes observed in the structure of these rodent communities. In Riparian (WR-2) the most likely causes for the recent declines in rodent density, species richness, and species diversity are the deposition of several inches of sediments on the rodent-trapping grid during a flash flood in August of 1982 and high stream flow and erosion during the springs of 1983 and 1984. In the aftermath of the 1982 flashflood, vegetation on a portion of the rodent-trapping grid changed radically: many shrubs (e.g., Chrysothamnus) and grasses have been replaced by coarse herbs (e.g., Sisymbrium altissimum). These vegetative changes have probably changed food resource availability (e.g., seeds) which strongly influences rodent community structure. In addition, montane vole populations go through cyclic changes that may be unrelated to prevailing environmental conditions.

The other vegetation type in which rodent density, species richness, and species diversity have declined sharply since the baseline period is Juniper

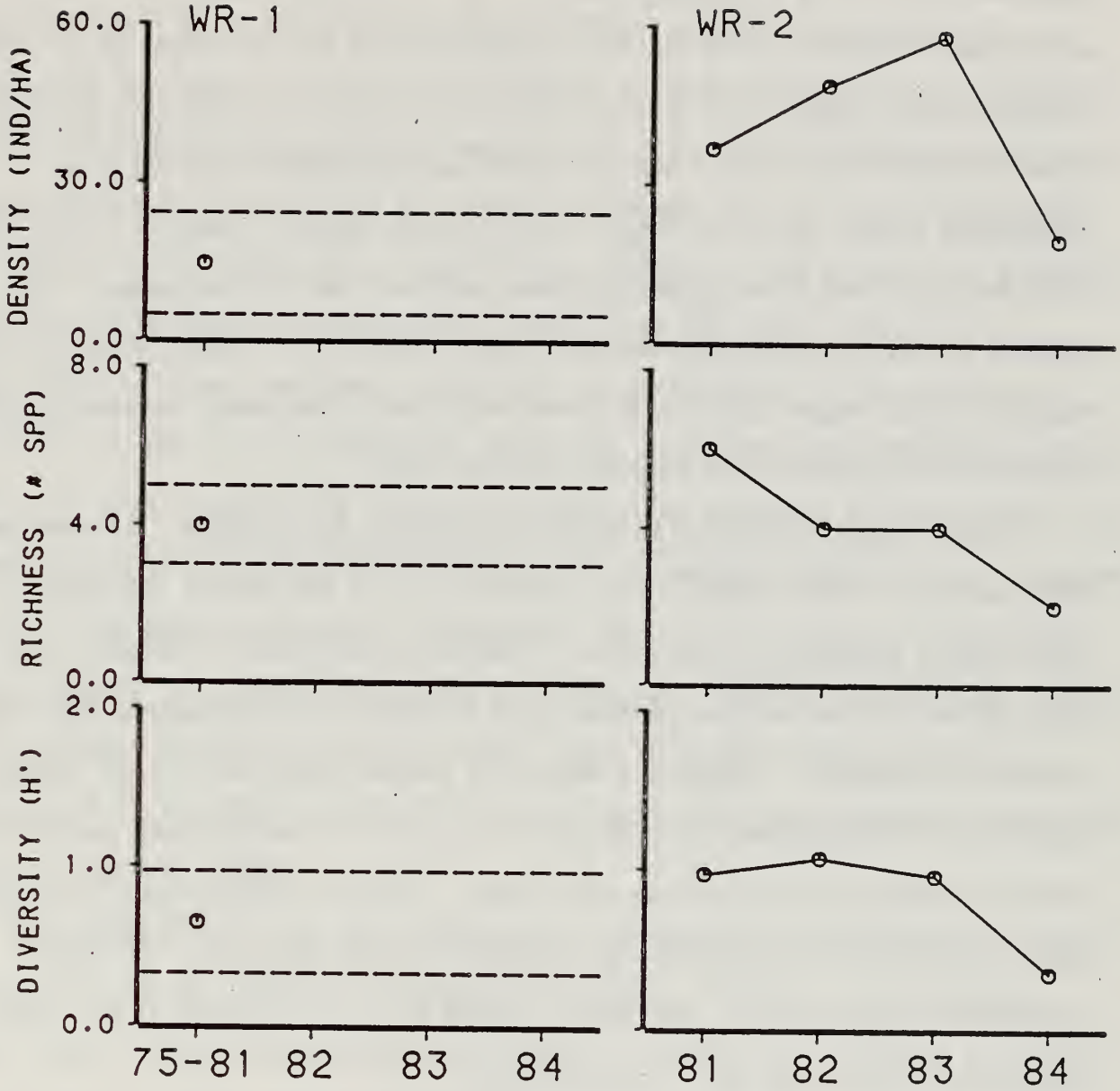

Fig. 5.4-27 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Riparian (WR-2) in August 1981 through 1984 compared to means (points) and 95% confidence limits (broken lines) during the baseline period (1975-1981) at a nearby Riparian site (WR-1).

(WJ-1). This site is approximately 2 km southwest of the plant site and is separated from it by high canyon walls. It is unlikely that the limited development that has occurred thus far could have had any significant effect on the rodent community at WJ-1. The severe winter of 1983-1984, however, may have resulted in the local extinction of several rodent species on WJ-1. Snow throughout tracts Ua-Ub in winter 1983-1984 was greater than 18 inches deep. This deep snow may have prevented some species from finding enough food. Rodents on WG-1 and WS-1 may not have been similarly effected because these habitats have deeper soils and, therefore, more sites where burrowing rodents can find refuge from cold temperatures and snow.

5.4.3.2 Desert Cottontails and Black-tailed Jackrabbits. Between August 1983 and April 1984, there was a sharp decline in the desert cottontail (*Sylvilagus audubonii*) population. Population densities in August 1983 were 1.82 ind/ha in Juniper and Shadscale, 2.75 ind/ha in Greasewood, and 3.38 ind/ha in Riparian. Assuming a mean of 2 ind/ha tractwide, Ua-Ub supported a population of 8300 desert cottontails. By April it was evident that the most of the rabbits had died during the winter. Several dead cottontails, many of which appeared to be untouched by predators, were observed. No desert cottontails were seen on the tracts during a five day period in mid April; two individuals were seen near Cowboy Canyon.

Transect censuses in June and July determined that desert cottontails were rare or absent in all vegetation types (Table 5.4-14). The largest population was found in Shadscale with 0.15 ind/ha in June and 0.27 ind/ha in August. No cottontails were seen in Riparian during censuses but one was seen off transect in August.

Causes for reduction in the population are unknown, but two factors may have contributed to the decline. The presence of numerous dead cottontails

that were not killed by predators suggests that disease, perhaps Tularemia, may have been a contributing factor. Snow depth on the site reached approximately 60 cm (18 in), the highest level since the measuring of precipitation began in 1975. This increase in snow depth may have made much of the cottontail's food supply inaccessible, causing nutritional stress and making them more susceptible to disease. However, the fact that many dead cottontails were observed in August 1983, indicates that disease was probably already widespread in the cottontail population and that a decrease in population size was imminent regardless of the severity of the winter.

The length of the cottontail cycle (i.e., peak to peak) depicted in Fig. 5.4-28 is seven years. The cottontail population remained low for about four years during the period 1978 to 1981. It is premature, with only one complete cycle of the desert cottontail documented, to conclude that all cycles will have a length of 7 years with peaks in cottontail density separated by 4 years of low rabbit density. But it is likely that cottontail populations will remain low on the study tracts for several more years and then peak again some time in the late 1980s.

Documentation of the highs and lows in lagomorph populations will play a vital role in the timing of revegetation efforts. Ideally, revegetation should begin when the cottontail population is declining to ensure success in plant establishment. This will give the plants about 4 years to establish in the absence of cottontail browsing. When young plants are available during peak cottontail density, the plants will be heavily browsed and protective measures will be required for successful plant establishment. The protective measures will increase costs of plant establishment.

Black-tailed jackrabbits (Lepus californicus) were not recorded on flushing transects in 1984. Some individuals were seen off transect in Juniper during April, June, and August. No individuals were seen in

Table 5.4-14 Density of desert cottontails (ind/ha) in 1984.

Month	Census Time	Habitat			
		Greasewood	Juniper	Shadscale	Riparian
June	AM	0.00	0.04	0.15	0.00
August	PM	0.04	0.00	0.27	0.00

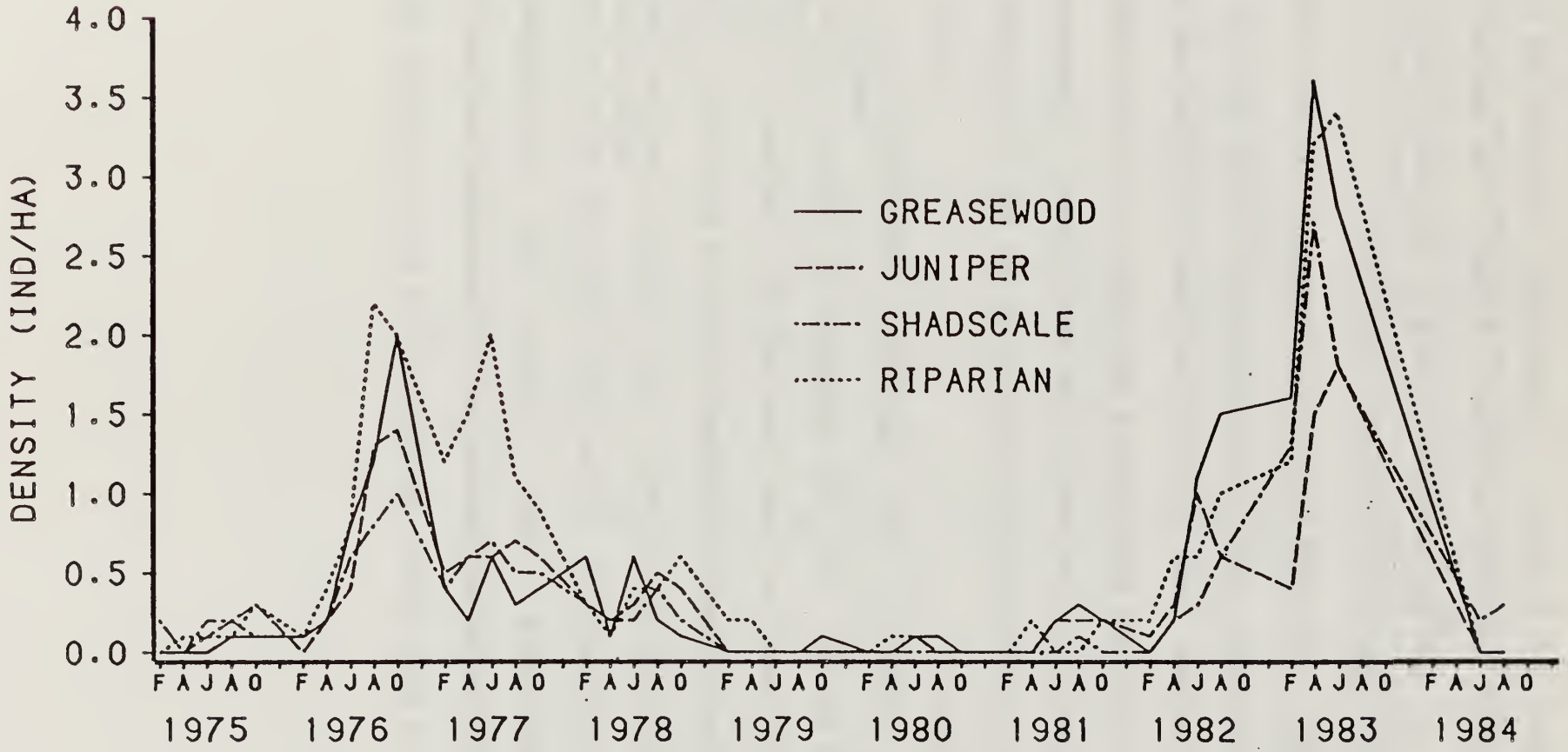

Fig. 5.4-28 Density (ind/ha) of desert cottontails in four habitats, bimonthly, from 1975 through 1984.

Shadscale, Greasewood, and Riparian. In August 1983, black-tailed jackrabbit had reached the highest densities recorded in 9 years. The apparent population decline in 1984 may have been caused by the severe winter or through disease contracted from the desert cottontail.

5.4.3.3 Big Game. Mule deer (*Odocoileus hemionus*), the most common big game animal on Tracts Ua-Ub, were frequently sighted during sampling sessions in April, June and August. Most sightings were made in juniper and shadscale habitat. Pronghorn antelope (*Antilocapra americana*) were seen in small numbers on the shadscale plains north of the White River. Bighorn sheep (*Ovis canadensis*), which were recorded on Tracts Ua-Ub for the first time in 1983, were not seen in 1984.

There were 37 sightings of mule deer made in 1984 totaling 108 individuals (Table 5.4-15). Mule deer abundance in 1984 was similar to 1982 (37 sightings of 122 deer) and lower than 1983 (52 sightings of 191 deer). However, the decrease in density compared to 1983 is due in part to decreased opportunity to make sightings in 1984. Along flushing transects, where sampling effort is standardized, 15 deer were seen along 80 km of transect in 1984 or 0.19 deer/km (Table 5.4-16). In 1982 and 1983, deer abundance was 0.11 ind/km and 0.24 ind/km, respectively. In this comparison, mule deer abundance in 1984 is more similar to that of 1983 than to that of 1982.

Table 5.4-15 Mule deer observed (both on and off flushing transects) on or near Utah Oil Shale Tracts Ua and Ub in 1984.

	Month		
	April	June	August
Number of Sightings	11	9	17
Greasewood	1	0	3
Juniper	2	5	9
Shadscale	6	2	6
Riparian	2	2	1
Number of Deer	50	20	38
Bucks	0	2	6
Does	0	14	27
Fawns	4	0	5
Unclassified	46	4	0
Mean Herd Size	4.5	2.2	2.2

Table 5.4-16 Abundance (individuals/km) of mule deer along flushing transects in June and August, 1984.

Transect	June	August	Total Kilometers Censused	Deer/km
WG-1	0	0	10	0.00
WG-3	0	0	10	0.00
WJ-1	0	4	10	0.40
WJ-5	0	4	10	0.40
WS-1	0	0	10	0.00
WS-4	0	5	10	0.50
WR-1	1	0	10	0.10
WR-2	0	1	10	0.10
Total kilometers censused	40	40		
Deer/km	0.03	0.35		

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Chapter 6.0

6.0 WATER RESOURCES

6.0 WATER RESOURCES

6.1 INTRODUCTION

The water reosurces monitoring program for the White River Shale Project (WRSP) was initiated in August 1974, and has continued without interruption to the present time. This section of the Progress Report discusses work performed during the period October 1, 1983 through September 30, 1984, which is referred to as the 1984 water year.

The 1984 water year monitoring program involved monitoring of surface water, ground water and hydrometeorology (precipitation and evaporation) on and near the tracts. It also included the documentation of efforts to meet the Quality Assurance and Quality Control (QA/QC) program objectives as described in the Environmental Monitoring Mannual (WRSOC 1982), hereafter referred as the EMM, and a technical memorandum (VTN 1982a) for this project. During the 1984 water year, field data collection was performed by WRSOC personnel, under the direction of VTN/Harmsworth Associates. VTN/Harmsworth Associates was responsible for data reduction, analysis, and the preparation of reports for the water resources program.

In addition to the WRSP monitoring program, the United States Geological Survey (USGS) has conducted its own water resources data collection program in the southeastern Uinta Basin throughout the project life. During the 1984 water year, the USGS efforts involved collection of streamflow and water quality data in the immediate vicinity of the tracts. The WRSP surface water monitoring program was designed to be used in conjunction with portions of the USGS program to meet monitoring objectives for the project. All USGS data presented in this report (USGS 1985) are preliminary and subject to revision, since they were "provisional" at the time of report preparation.

6.2 SUMMARY

6.2.1 Hydrometeorology

The 1984 water year was the third consecutive year of above average precipitation with a tract average of 14.78 inches. This was the highest annual average exhibit during the 10 years of precipitation monitoring at tracts Ua-Ub. The wet 1984 water year increased the 10-year tract mean to 10.36 inches. Of the eleven gauges on tract, the maximum precipitation collected was 16.82 inches at RA-4, with RS-11 reporting the low of 13.71 inches.

Analysis of the effects of elevation on total precipitation, revealed a pattern of increasing precipitation with elevation only a drainage specific basis. The only deviation from this pattern appeared at stations along the White River during late spring through early fall.

Review of seasonal precipitation totals revealed a large increase in the 1984 spring preciptriation compared to the six year seasonal mean (230% above normal). Fall and summer were moderately above normal, with reported increases of 14 and 34%, respectively. Winter data showed below normal precipitation (-1.2%).

The most significant rainfall events were recorded on February 14 and June 6-7, 1984. These events resulted in a 6-hour event of 0.80 inches for both dates and a 12 and 24-hour event of 1.10 and 1.40 inches, respectively on June 6-7. This 24-hour event, recorded in Plant Site Wash, matched the previous tract maximum.

Pan evaporation in Plant Site Wash (EVP-1) totaled 35.61 inches, between June 1 and October 15, 1984. During the same period evaporation in

Southam Canyon (EVP-9) totaled 22 43 inches. While the station evaporation ratio (EVP-1/EVP-9) varied month-to-month, EVP-1 consistently reported greater evaporation. The average ratio for June through October was 1 59 with a maximum of 1.74 in July and a minimum of 1.30 in October.

6.2.2 Surface Water

Total runoff for the 1984 water year was the greatest in the 10-year period of record at Evacuation Creek station 6430. The mean annual discharge of 12.7 cfs far exceeded the prior 9-year mean of 2.80 cfs. The increased streamflow in 1984 was due to above normal snowmelt runoff from March to June and from several intense thunderstorms over the summer months. Water quality data collected at Evacuation Creek during 1984 was very similar to the baseline results.

The plant Site Wash station 6602 (below the Retention Dam) recorded one small runoff event (0.10 acre-feet) during 1984. No water quality or suspended sediment data were collected at this station in 1984.

A monitoring program at the Retention Dam Pond (RES-1) was initiated in 1984 to provide data regarding: 1) the volume of water retained in the pond: 2) the water quality characteristics, and 3) to estimate any subsurface leakage from the pond by conducting a water balance study. The contents of the reservoir was 1.9 acre-feet on May 8 when weekly stage observations were initiated. This water was believed to be derived primarily from mine drainage following penetration of the Birds Nest Zone in the mine shaft and decline. The reservoir reached a peak volume of 3.70 acre-feet on July 10, following several intense thunderstorms in June and early July. Monthly specific conductance readings at the reservoir indicated an inverse relationship with volume. The lowest specific

conductance of 3130 micromhos occurred at the highest volume, while the highest specific conductance of 4720 micromhos occurred near the end of the water year when the volume had declined to 2.80 acre-feet. Water quality samples indicated that the reservoir was very similar in character to ground water from the Birds Nest Zone (sodium-sulface).

Several organic constituents, including total phenols, dissolved organic carbon, and nitrate plus nitrate, were higher in concentration than natural tract waters. An organic-based grouting material used in sealing the Birds Nest Zone in the mine shaft and decline, was believed to be the cause of these high values. Because the sealing of the Birds Nest Zone was performed one time during 1984, these values are anticipated to have returned to normal concentrations.

A water quality sample collected from the seepage collection pit below the retention dam, indicated that this water was derived from local runoff and not from leakage through the dam. A water balance analysis of the Retention Dam Pond was not conducted in 1984 due to the gross measurements of storage, runoff, and evaporation.

Runoff at Southam Canyon Wash station 6610 during 1984 was only 5.9 acre-feet, compared to the 9-year mean annual runoff of 30 acre-feet. Because of the difficulties in monitoring flows from dry washes, several significant runoff events may have been unrecorded at this station. No water quality or suspended sediment samples were collected at this station in 1984.

Asphalt Wash station 6625 was taken over from the USGS and operated by WRSOC in 1984. The total runoff of 19 acre-feet was very low compared to

the 9-year mean of 157 acre-feet. However, several significant runoff events were probably not recorded in 1984.

The 1984 mean annual runoff for White River station 6700 was the second highest in the 61 years of streamflow records collected on the river. Only the 1929 water year, with 1736 cfs, exceeded the 1984 mean annual runoff of 1355 cfs. The 1984 water year was the second consecutive high flow year and (as in 1983) the runoff was derived primarily from the heavy snowmelt runoff from the upper basin. The peak flow during 1984 occurred on June 9 with 6420 cfs. This peak flow did not approach the historic peak of 8160 cfs recorded at station 6500 in 1929. Water quality and suspended sediment data collected at the White River in 1984 were generally within the range of baseline values, with a few exceptions.

Several parameters exceeded baseline maximums on the April sample including calcium, magnesium, sulfate, alkalinity, total hardness, non-carbonate hardness, ammonia, nitrate, nitrite plus nitrate, ortho phosphorus, and boron. These usually high values were attributed to the contribution of lower basin runoff (i.e., Evacuation Creek), which is commonly high in these constituents. Also, the June water quality sample showed unusually high values for suspended solids and chemical oxygen demand. These exceedences were attributed to the high flows from upper basin runoff. Because these high values were detected at both the upstream (6510) and the downstream (6615 or 6700) White River stations they are likely due to natural variations or from project activities not related to the WRSP. Statistical tests of the concurrent water quality data collected at the upstream and downstream stations verified there was no significant difference between stations.

6.2.3 Ground Water

The 1984 water levels in the Birds Nest Zone were generally within ranges previously observed during baseline investigations. Wells P-2 ranges previously observed during baseline investigations. Wells P-2 Lower, G-11, G-15 and G-21, which exhibited water level declines from 1981 through 1983, began to show some recovery in 1984. The cause for decline and recovery is not completely understood, but is believed to be a result of discharge-recharge change (i.e., pumping) which may be occurring off tract. Contrary to the other Birds Nest wells, well G-5 remained at a fairly stable water level in 1984. The most substantial water level change in 1984, was the 15.45 foot rise in Well G-10 between January and April. The water quality of the individual wells sampled in the Birds Nest Zone appears to be generally unchanged from baseline conditions. However, some increases in certain parameters, notably iron and manganese, were well above baseline conditions and are believed to be a result of contamination from the well casing.

Water levels and water quality in the Uinta Formation well, P-2 Upper, remained within the range of baseline conditions. A gradual rise in the water level of P-2 Upper occurred from December until the end of the water year. Slight increases in certain water quality parameters were also noted in 1984, however, they most likely represent natural variation. In the Southam Canyon alluvium, (well AG-6-1 Lower) water levels and water quality have remained unchanged from baseline conditions.

Several monitoring wells were completed in August and September 1983, to monitor ground water conditions in the Unita Formation and alluvium surrounding the Retention Dam in Plant Site Wash. Measurements of water

levels in the wells indicated water bearing zones in the Undifferentiated Uinta Formation (UNDIF), Grey Marlstone Unit (GMU), Intermediate Zone (IZ) and the Lower Uinta Gradational Zone (LGZ). The water bearing zones all appear to be under unconfined (water table) conditions, with the exception of the LGZ. Water quality samples collected from each of the zones typify the ground water as a sodium-sulfate type water. This corresponds to what would be expected of water percolating through the Uinta Formation and dissolving thenardite (Na_2SO_4). The LGZ exhibited the lowest concentration of total dissolved solids (4050 mg/l), which may suggest that recharge has been occurring for sometime in this zone.

6.3 PROGRAM DESCRIPTION

The water resources program has been designed to document and assess potential project-related impacts on the hydrologic environment. To fulfill this objective, the 1984 program continued to collect background (pre-construction) data for tract water sheds and ground water systems which could be, but have not yet been affected by project development activities (i.e., Southam Canyon Wash). Project activities conducted during the 1984 water year included completion of the mine ventilation shaft and decline and disposal of overburden in Plant Site Wash. The monitoring activities, particularly at stations that could be impacted by these construction activities, were designed to allow identification of project-related impacts by comparing concurrent data to data collected at control stations and/or by comparing current data to previously collected baseline data.

The water resources monitoring stations have been located so as to detect: (1) unplanned point surface discharges, such as accidental spills or leaks from retention dams or impoundments; (2) non-point surface discharges, such as runoff from areas of road construction and other project activities; and (3) point and non-point source seepage into local ground water systems.

This report uses the USGS system of nomenclature for surface water stations numbers (8 digits) as opposed to previous reports where dual nomenclature systems were used. For convenience, only the last four digits of the USGS surface water station numbers are used in the test (since the first four digits, 0930, are always the same).

6.3.1 Hydrometeorology

The hydrometeorological program (i.e. the measurement of precipitation and pan evaporation) is designed to collect and analyze climatic data useful to hydrologists, engineers and reclamation specialists. The data provided by the 1984 program has expanded the data base which gives more insight into the temporal variations of precipitation which occur at the project site. The definition of these variations will prove invaluable in the interpretation of data collected by other disciplines. The climatic data should also be considered in the design of project components such as process shale disposal road construction and maintenance, and water availability for revegetation programs. The latter will make the most use of climatic data for design of a cost effective program.

The 1984 hydrometeorological program corresponds with the 1983 program with two major exceptions. The first concerns a change in the evaporation program. In 1983, evaporation station EVP-13 was cancelled due to construction activities and was not brought back into service. In 1984 a new evaporation station was established at the retention dam. This station, designated EVP-1, consists of a Class A evaporation pan, a recording hygrothermograph in an instrument shelter, and a totalizing wind run anemometer. The second network modification involved the precipitation gauge at Air Station 13. Prior to June 1, 1984 the precipitation gauge at this site was a weighting type automatic recording gauge. Following the establishment of EVP-1, the automatic gauge was moved to the retention dam and designated ARA-1. The automatic gauge at Air Station 13 was replaced with a storage type gauge.

To supplement data collected on the tract, regional climatic data collected by the National Oceanic and Atmospheric Administration (NOAA) have been included where appropriate.

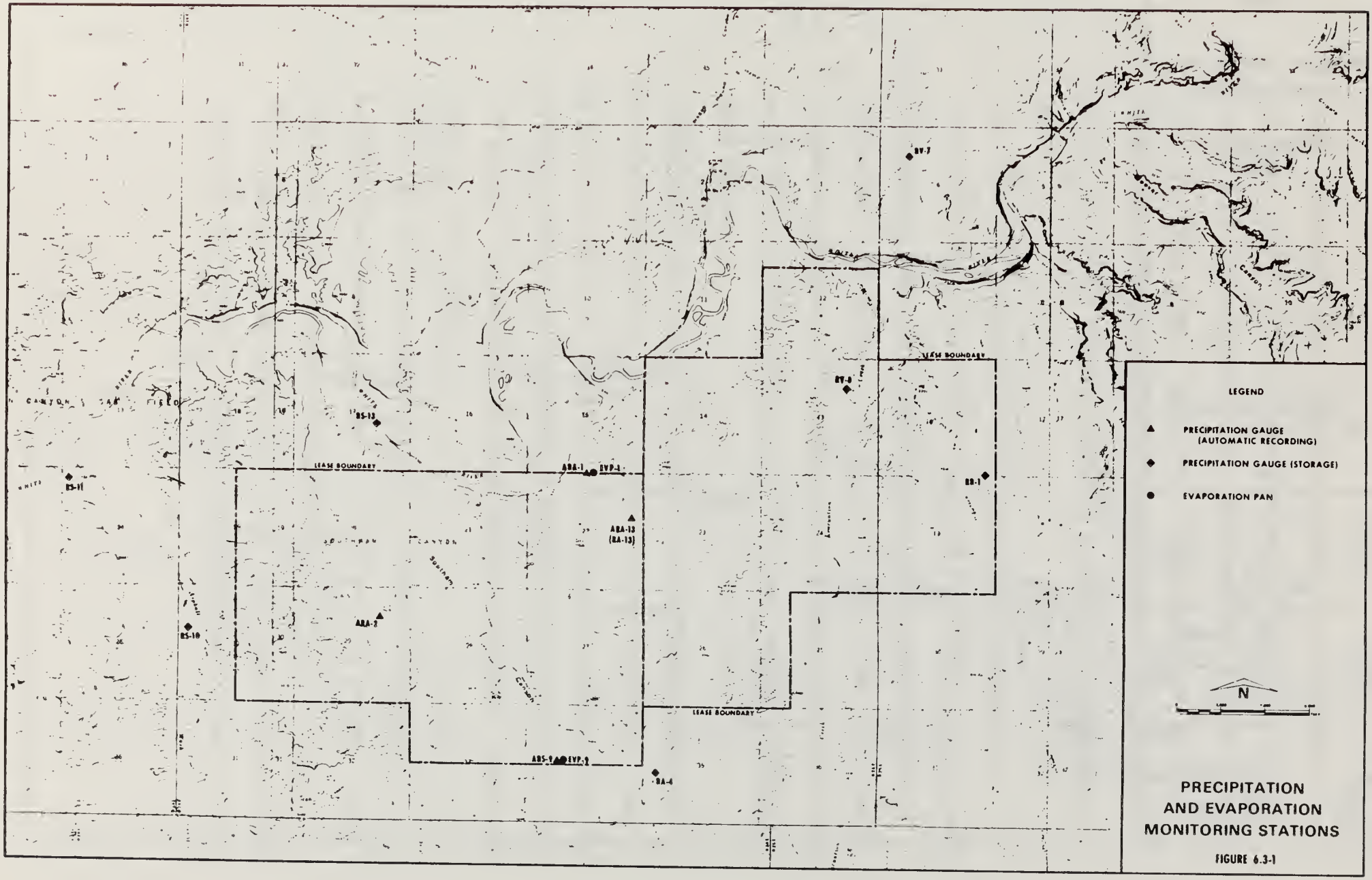
The hydrometeorological stations operated during the 1984 water year are shown in Figure 6.3.1.

6.3.2 Surface Water

The surface water monitoring program is designed to determine the quantity and quality of surface waters surrounding Tracts Ua and Ub. A total of 9 surface water stations were monitored during 1984 and are shown in Figure 6.3-1. There are five stations upstream of WRSP activities (6430, 6500, 6510, 66-5 and 6625) that serve as control sites. These stations are unaffected by WRSP activities and monitor natural or non-project related hydrologic events and fluctuations. Stations located downstream from project activity (6602, 6610, 6615, and 6700) are designated as treatment stations and monitor the potential effects of project activities in each drainage basin.

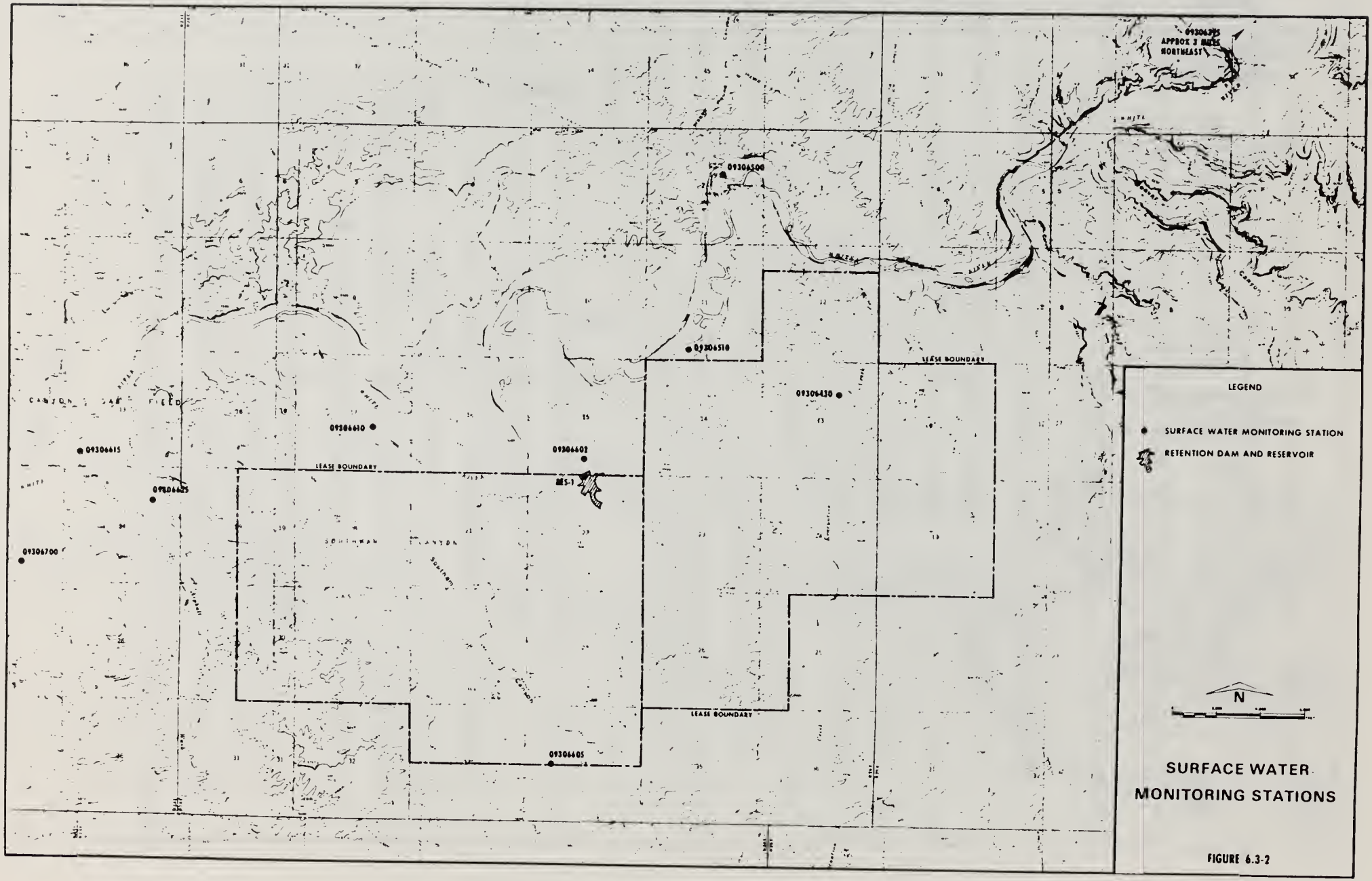
The 1984 surface water monitoring program was designed as described in the EMM. The following changes were implemented in 1984:

- Discontinued use of White River Station 6395 for water quality comparisons. This station provided a poor comparison to downstream station 6700, because of the inflow of Evacuation Creek between the stations. The USGS streamflow records at this station were still utilized for determination of Lower Basin runoff.
- Utilization of two new White River stations, 6510, and 6615, for water quality comparisons. Use of these stations eliminates the effects due to inflows from the non-impacted tributaries, Evacuation



PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 6.3-1



SURFACE WATER MONITORING STATIONS

FIGURE 6.3-2

Creek and Asphalt Wash. The only tributary inflows between these stations are Plant Site Wash and Southam Canyon Wash, which now allows more rigorous statistical comparisons for detection of project-related impacts. Concurrent (same day) water quality measurements continued to be collected for field parameters on a bi-weekly schedule and for laboratory parameters on a quarterly basis.

- The collection of continuous water temperature and specific conductance records was moved from White River Station 6395 to 6510. As discussed above, this relocation eliminates the effects of Evacuation Creek inflows. The mean daily values for this control station were compared with Station 6700. (Station 6700 could not be moved to new location at 6615 because no power supply existed at this station).
- Suspended sediment sampling on the White River was reduced from bi-weekly to quarterly due to the reduction in construction and grading activities in 1984. Also, the upstream control station for sediment sampling was changed from 6395 to 6500, while Station 6700 continued as the downstream station (these changes were limited to stations with cableways).
- Due to the lack of project activities in Evacuation Creek, no suspended sediment samples were collected and only one water quality sample was taken (reduced from quarterly).
- WRSOC took over operation of the Asphalt Wash Station 6625 operated previously by the USGS. Continuous streamflow records were

collected in 1984, however, suspended sediment and water quality sampling were discontinued.

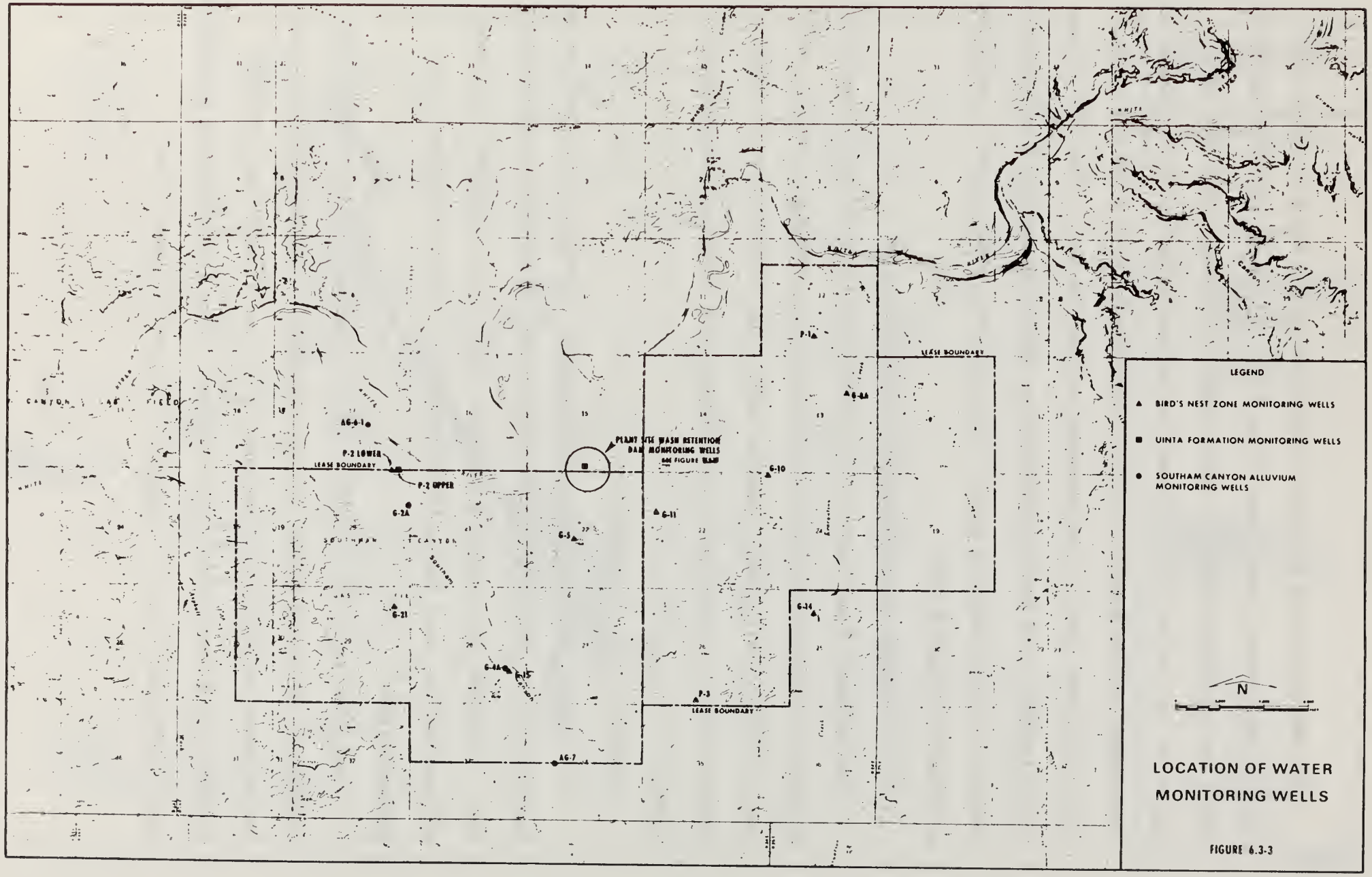
- A quarterly water quality sampling program was implemented on the newly created Retention Dam Pond (RES-1). This program also included weekly measurements of stage and monthly measurements of water temperature, pH, dissolved oxygen, and specific conductance. The procedures for monitoring the Retention Pond were documented in a Technical Memorandum (VTN 1984a).

6.3.3 Ground Water

The objectives of the 1984 water year ground water monitoring program were to: 1) expand the record of background conditions for water levels and water quality in the Uinta Formation, Southam Canyon Wash alluvium and certain areas of the Birds Nest Zone; 2) study possible effects in the Birds Next Zone due to dewatering and grouting at the mine ventilation shaft and decline; and 3) monitor possible ground water effects to the alluvium and Uinta Formation in Plant Site Wash from construction and storage of waste water at the retention dam.

For most of the water year, a total of 22 wells were used for ground water monitoring. Of these, 10 are in the Birds Next Zone, seven in the Uinta Formation, four in Southam Canyon Wash alluvium, and one in Plant Site Wash alluvium. The location of all monitoring wells is shown on Figure 6.3-3.

All data collection for the ground water program was in conformance with the planned monitoring schedule specified in the EMM as currently revised, with a few minor exceptions.



LOCATION OF WATER MONITORING WELLS

FIGURE 6.3-3

Six new monitoring wells were installed in the Uinta Formation and alluvium immediately downstream of the Plant Site Wash retention dam during August and September 1983 (VTN 1984b, 1984c). At that time, well UF-1 (which was designated a Uinta Formation monitoring well from its completion in December 1982 to August 25, 1983) was recompleted as a multiple-tube well, and is now part of the retention dam well network. The main purpose of the network is to measure ground water conditions and to detect potential leakage from the retention pond. The locations of the retention dam wells are shown on Figure 6.3-4.

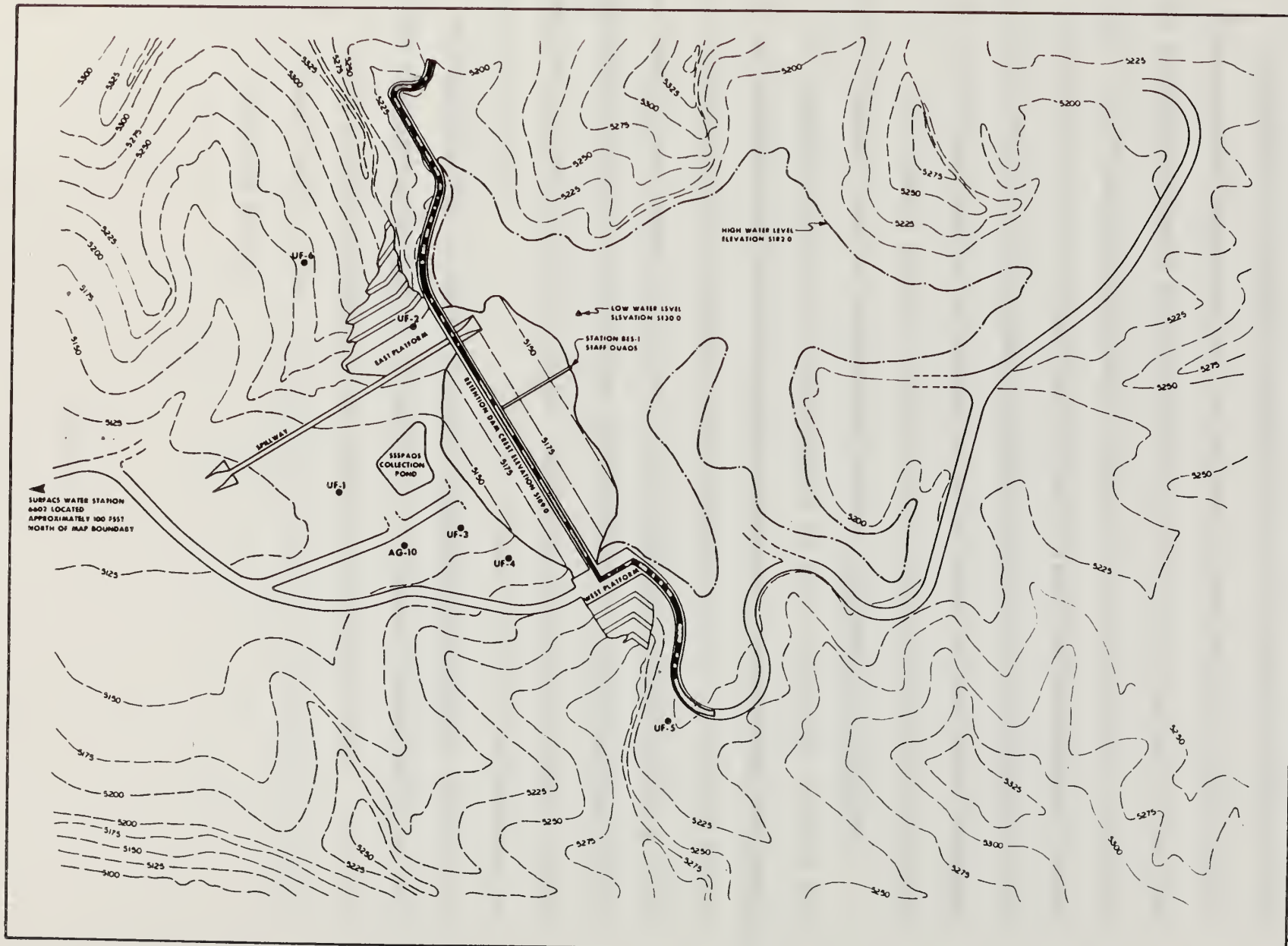
6.3.4 Quality Assurance/Quality Control Program

The purpose of the quality assurance/quality control (QA/QC) program is to ensure the accuracy, precision, completeness, representativeness, and comparability of all water resources data. The rationale for the QA/QC program design is described in the EMM and in a technical memorandum (VTN 1982a).

6.3.4.1 Field Procedures

A. Routine Maintenance and Calibrations. Standard field methodology specified by the USGS and the EPA was employed throughout the 1984 water year. Personnel involved in field data collection, instrument operation, and calibration, were thoroughly familiar with proper procedures and methodologies.

The WRSOC field hydrographer routinely checked and maintained field instruments to verify proper working condition. Malfunctioning equipment was repaired or calibrated immediately. All maintenance was performed according to manufacturers specifications. Complete records of maintenance and calibration are kept in separate instrument history files.



WHITE RIVER SHALE PROJECT
WATER RESOURCES PROGRAM

PLANT SITE WASH RETENTION DAM AND MONITORING WELLS

LEGEND

- MONITORING WELL
- GROUT CURTAIN, SOLID IN AREAS OF ABOVE-AVERAGE GROUT TAKE (OVER 2.0 SACKS CEMENT PER STAGE)
- HIGH WATER LEVEL IN IMPOUNDMENT, ELEVATION 5182.0
- LOW WATER LEVEL IN IMPOUNDMENT, ELEVATION 5130.0

NOTES
ELEVATION OF GROUT CAP IS 5185.0 ON ABUTMENTS SLOPING TO 5100.0 BELOW CENTER OF EMBANKMENT
MAP DEVELOPED FROM RALPH M. PARSONS CO DWGS D-72 CE-27 28 54 55 5A AND RUNOFF RETENTION DAM SITE PLAN (AS BUILT)

SCALE 1 : 1200
100 0 100 200
SCALE IN FEET

DATUM IS MEAN SEA LEVEL

FIGURE 6.3-4

Installation of continuous recorders, sensors, and shelters during the 1984 monitoring period was done according to USGS guidelines.

B. Independent Inspection. On September 18 and 19, 1984 an independent inspection of all WRSP water resources equipment was performed by Watec, Inc. of Aurora, Colorado. As in previous years, Watec's scope of work included: 1) inspection and calibration of all water quality instrumentation used in the water resources program, utilizing Watec's references and solutions; 2) testing and verification of the WRSOC thermometer; 3) inspection of the suspended sediment laboratory equipment; 4) inspection of all field equipment used for water resources program (such as current meters and stage recorders); and 5) submittal of a report (Watec 1984) describing the findings of the equipment audit and corrective actions taken.

C. VTN Field Inspections. During the 1984 water year, periodic visits were made to the project site by VTN/Harmsworth Associates personnel to inspect the performance of the WRSOC hydrographer and the condition of the project equipment. Inspections were made of precipitation and evaporation stations, well sampling equipment, retention dam stations, and surface water stations and equipment. Inspections were made by specialists in hydrometeorology, surface water and ground water. Results of field trip inspections are reported on field trip summary forms.

6.3.4.2 Laboratory Procedures. During February, 1984 a changeover from the USGS Central Laboratory to Bookcliffs Commercial Laboratory was initiated. Additional QA/QC procedures were implemented during this

changeover to ensure the comparability of the data from the two labs and the overall accuracy, reliability and precision of the new lab values. The new procedures implemented included:

1) Participation in the USGS Standard Reference Water Sample (SRWS) program. This program provided a comparison of Bookcliffs' values against the mean values determined by all the participating laboratories in the program.
2) Duplicate samples testing by Bookcliffs and USGS labs.

Bookcliffs' internal Quality Assurance Program included the following:

1) Participation in the EPA standard sample testing program.
2) Duplicate analysis testing randomly run on ten percent of samples submitted.
3) Spiked sample testing randomly run on ten percent of samples submitted.
4) QA/QC reports submitted quarterly detailing the results of 1, 2, and 3 above and any corrective action taken.

Three QA/QC reports, dated July, August, and October, 1984 were submitted by Bookcliffs Commercial Laboratory. In addition, a memo (VTN 1984d) discussed the results of the initial 12 SWRS samples and two duplicate samples.

In addition to the above QA/QC procedures, the following routine checks on all lab data performed in the office by VTN/Harmsworth Associates:

1) The cation/anion balance is within 2.5 percent.
2) Consistency of the relation between specific conductance and total dissolved solids.

3) Ensure that time critical analyses were run within specified time limits.

4) Reporting of the proper lower limits of detection.

5) Reporting of the proper sample identification.

6) Use and documentation of standard laboratory procedures.

Laboratory analyses for suspended sediment sample concentrations were performed in WRSOC's site laboratory trailer. The balance used for weighing samples was typically checked on a monthly basis, in accordance with the air resource QC program. Laboratory methods for determination of suspended sediment concentration are standard methods used by the USGS (Guy, 1969).

6.3.4.3 Office Procedures

A. Data Review and Log-in. All data received were immediately logged in the WRSP logbook and were then checked for completeness, accuracy and readability. The data were then routed by the data coordinator to a discipline specialist or data technician, depending on the action to be taken. A document control form accompanied all data during routing to various persons to record the chain-of-custody.

B. Data Entry and Verification. All data entry into the WRSP water resources computer data management system was performed by a qualified data technician. All data entered manually were verified by another environmental scientist who checked the digital printout against the original data report. The correct and verified printout was initialed and kept in the data files. Digital tape data were checked by the appropriate discipline specialist after computer entry. Once checked and found to be correct by the discipline specialist, the data were considered verified. Water levels, field

water quality and discharge measurement data were summarized by appropriate discipline specialist before entry. In such cases, entry was checked by a discipline specialist against the summary sheet.

C. Computer Tabular and Graphical Output Verification. All output tables and graphics produced by computer were checked by the author of each section of a report. The outputs were checked against the verified data.

D. WRSO Data Files. All WRSP water resources data are kept in file drawers with the exception of the digital tapes. The tapes are kept temporarily in a separate two drawer file. After finalization of the records, the tapes are returned to the WRSOC Mine Services Building on the tracts. The files are organized by program, water year, station name and number, and subject (e.g., discharge, rating curves). All non-digital tape data are bound in manila folders.

E. Data Management Audit A quality assurance audit was conducted on the WRSP data management system. The purpose of the audit was to verify that the field and laboratory data processing and filing was done correctly. For the processing of data, the values reported on field and laboratory forms were compared against the values shown in the Progress Report. The project data files were reviewed to determine if they were maintained in a manner such that the data could easily be retrieved.

An audit report (Harmsworth Associates, 1985a) was prepared and placed in the project files. The report discussed the results of the audit and made recommendations for continued monitoring of the WRSP data management system.

F. Technical Report Preparation and Review Technical reports were prepared by the discipline specialists responsible for the data analysis involved in a particular section of the report. Environmental specialists, who had not been directly involved with the data analysis, in turn reviewed these sections for technical accuracy.

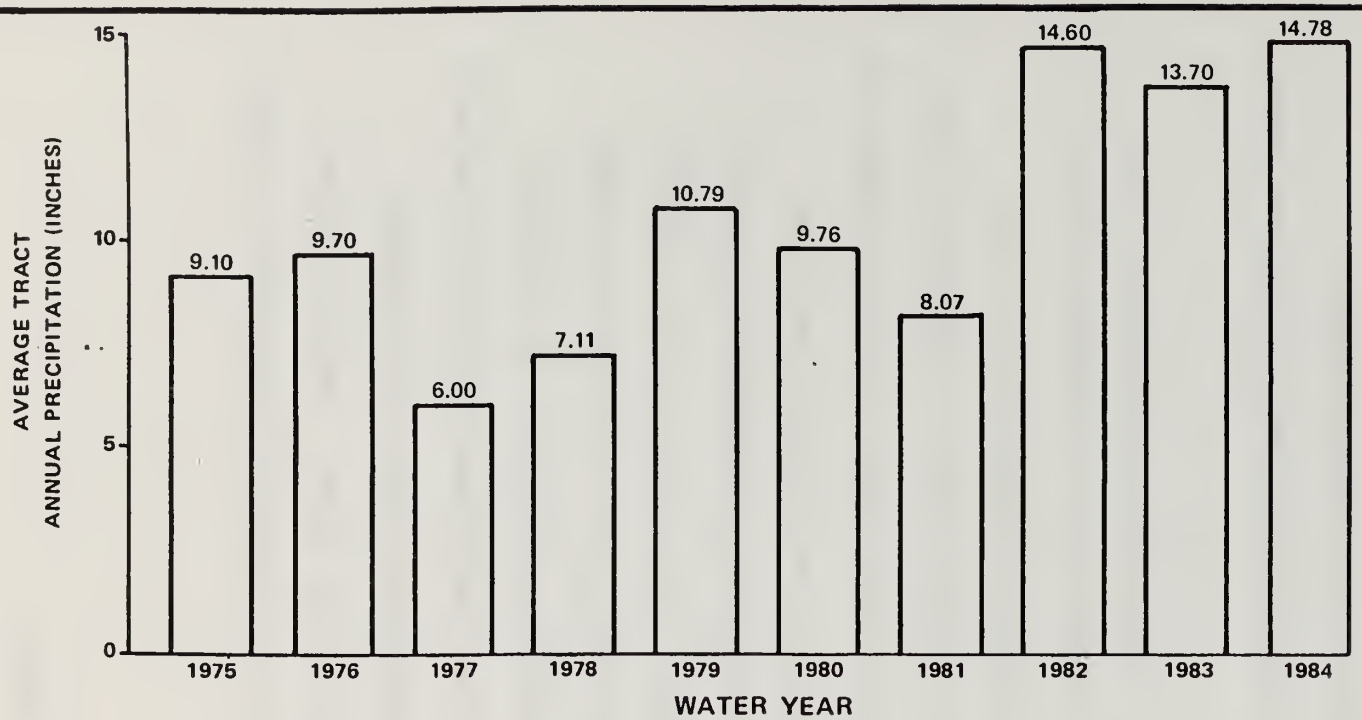
6.4 Results and Analysis

6.4.1 Hydrometeorology

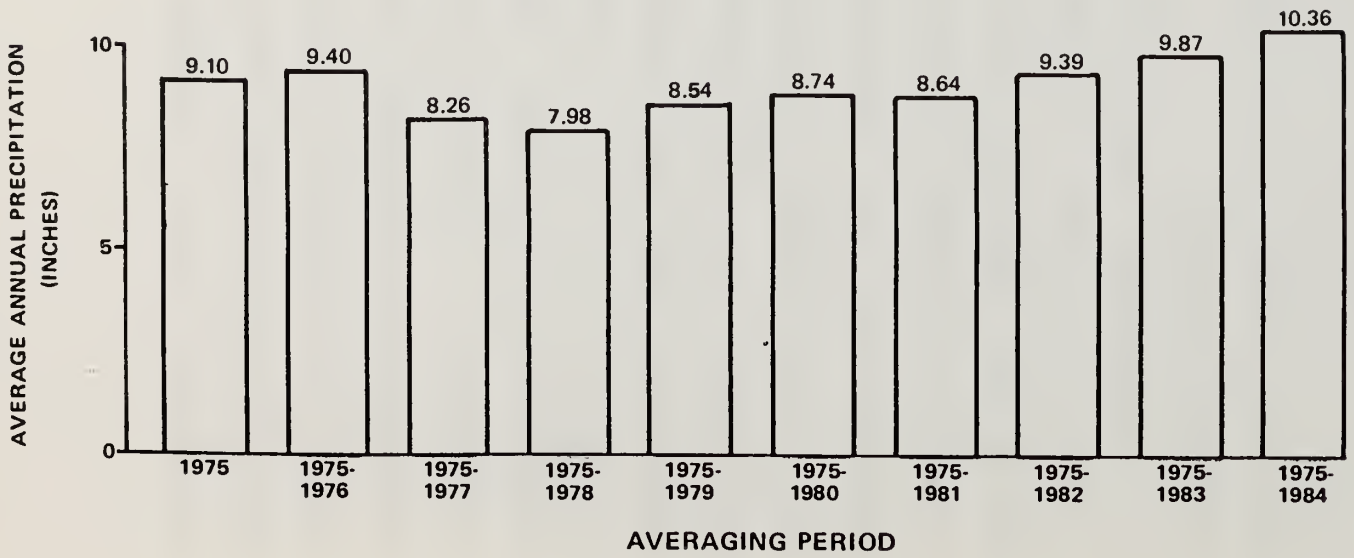
The following discussion of program results and analysis for the hydrometeorology program is divided into two general categories: Precipitation and Pan Evaporation.

6.4.1.1 Precipitation The 1984 water year was the third consecutive year in which annual precipitation totals were above normal in the Uinta Basin. At tracts Ua-Ub this was exhibited by an average annual precipitation total of 14.78 inches, exceeding the previous tract maximum of 14.60 inches in 1982.

The 1984 data brings the period of record mean (10 years) for the tracts to 10.36 inches. The average annual tract precipitation for each of the 10 years, beginning in 1975 is presented in Figure 6.4-1. Also presented in the figure are the yearly running averages, calculated at the end of each water year. As can be seen in the upper half of the figure, the year to year variation in precipitation for the tracts has declined considerable. The period from 1975 through 1981 (relatively dry years), experienced a mean annual precipitation of 8.64 inches, with a standard deviation of 1.68 inches. At no time during this period did the annual average exceed 11.00 inches. Since 1981 the variability has declined significantly. The last three years (wet years) have a mean annual value of 14.36, almost 6 inches above the previous seven years. The standard deviation for this period was reduced to 0.58 inches. The great annual variability which occurs at the tracts is evidenced by the period of record standard deviation of 3.09 inches.



ANNUAL TRACT MEANS
BY WATER YEAR



RUNNING AVERAGE OF TRACT MEAN

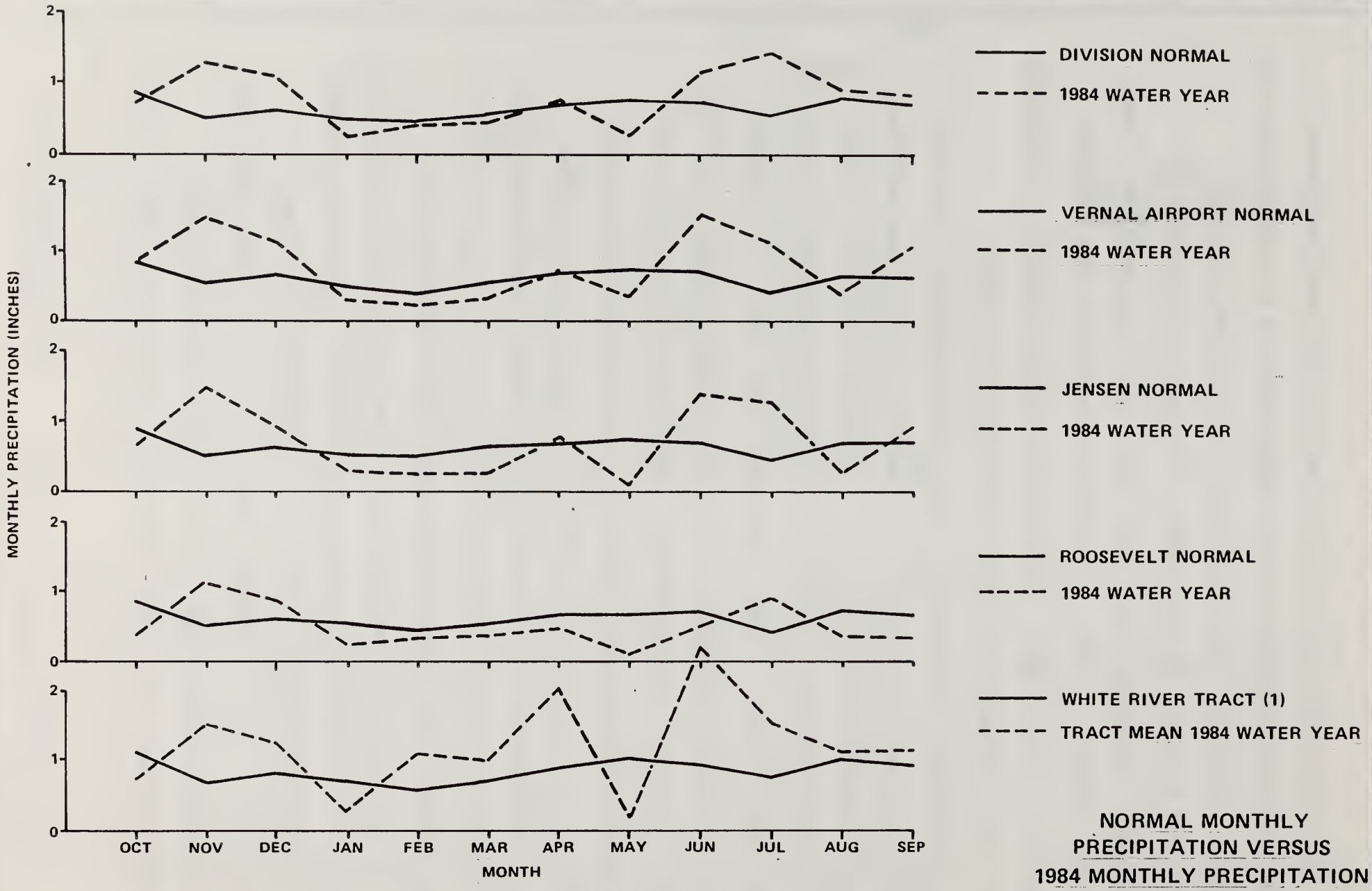
ANNUAL PRECIPITATION
MEANS FOR THE
WHITE RIVER TRACTS (Ua - Ub)

GURE 6.4-1

Since 1981, when the period of record tract mean was 8.64 inches, a steady increase in the annual mean of approximately 0.5 inches per year has occurred. This trend is a direct result of the extreme conditions experienced over the last three years. The onset of this trend also corresponds to the major 1982 El Nino event, which has been shown to have had global impacts. While it is generally accepted that the phenomenon known as El Nino has abated, lingering after-effects apparently continue to have a major influence on climatic conditions in this area.

The 1984 water year was 42.7% above normal compared to the 10 year tract mean annual precipitation. This deviation from the mean was also observed at other regional stations. For example, the Vernal Airport, Jensen and the Uinta Basin Division all reported annual totals greater than their respective 30-year normal (NOAA 1982, 1983, 1984). The Roosevelt station in the western portion of the basin, however, reported lower than normal precipitation (84% of normal). Figure 6.4-2 presents the 1984 monthly precipitation and 1951-80 normals for the Uinta Basin Division, Vernal Airport, Roosevelt, and Jensen. For comparison, the 1984 mean monthly precipitation Tracts Ua-Ub has been included. Excluding the value for February, the overall precipitation pattern for the tracts is similar to other stations in the region, although magnitudes are more extreme.

Of the 11 gauges in the WRSP network, the greatest annual precipitation occurred at RA-4 where 16.82 inches were collected. The station reporting the lowest annual total was RS-11 which accumulated 13.71 inches of precipitation. While this latter station low is not consistent with 1983, it does appear similar to the historic pattern. The tract low has alternated between RS-11, RS-13 and ARA-13. For each year that it has been



NORMAL MONTHLY PRECIPITATION VERSUS 1984 MONTHLY PRECIPITATION IN UINTA BASIN

(1) WHITE RIVER NORMAL BASED ON DIVISION NORMAL VALUES

FIGURE 6.4-2

in operation, RA-4 has collected the highest precipitation. The range in precipitation over the 11 gauge network for 1984 (3.11 inches), is not considered unusual for the varied terrain and storm conditions encountered in the vicinity of the tracts.

Previous investigations in the effects of elevation on precipitation, indicated that no defined correlation existed in the project area. This early investigation, however, was conducted on all operating gauges as a single set. A new analysis was conducted this on the effects of elevation on precipitation within each of the four major drainage basins on the tracts. The results of this analysis are presented in Table 6.4-1. The four drainages considered were Asphalt Wash, Southam Canyon Wash, Plant Site Wash and Evacuation Creek. On an annual basis all four drainages showed a clear pattern of increasing precipitation in an up basin direction. On a seasonal basis the pattern is still evident, however, exceptions do occur.

Southam Canyon Wash, which has the largest number of gauges of any drainage (two storage and two recording), displays the aforementioned pattern on an annual basis. On a seasonal basis, however, only spring maintains the pattern for all four gauges. In fall and winter, the gauge at the mouth of the canyon, RS-13, deviates from this pattern by being higher than the next upbasin gauge, ARA-2. This may be due to isolated events which affected only RS-13 or other terrain induced effects which are as yet undefined. Review of the summer data indicated that a single rain event occurring on July 23 contributed 0.80 inches to the ARA-2 monthly total while upstream at ARS-9 only 0.30 inches of rain accumulated for the same

TABLE 6.4-1

ANALYSIS OF PRECIPITATION VERSUS GAUGE LOCATION
WITHIN INDIVIDUAL BASINS
(inches)
(1983 values are in parentheses)

Basin	Gauge	Fall	Winter	Spring	Summer	Annual
Asphalt Wash	RS-11	3.46 (2.20)	2.19 (3.61)	4.49 (3.31)	3.57 (4.18)	13.71 (13.30)
	RS-10	3.21 (2.02)	2.26 (3.74)	5.02 (3.65)	3.85 (5.10)	14.34 (14.51)
Southam Canyon Wash	RS-13	3.58 (2.33)	2.48 (3.58)	4.50 (3.41)	3.60 (5.10)	14.16 (14.42)
	ARA-2	3.00 (1.90)	2.10 (4.00)	4.60 (4.20)	4.70 (4.00)	14.40 (14.10)
	ARS-9	3.30 (2.10)	2.60 (4.20	5.20 (4.20)	4.30 (4.03)	15.40 (14.53)
	RA-4	3.79 (2.26)	2.98 (4.16)	5.39 (4.57)	4.66 (3.91)	16.82 (14.90)
Plant Site Wash	ARA-1	*3.00 (N.D.)	*1.90 (N.D.)	*4.20 (N.D.)	3.10 (N.D.)	*12.20 (N.D.)
	ARA-13	3.80 (1.60)	2.30 (3.10)	4.99 (4.00)	3.77 (2.80)	14.86 (11.50)
	RA-4	3.79 (2.26)	2.98 (4.16)	5.39 (4.57)	4.66 (3.91)	16.82 (14.90)
Evacuation Creek	RV-8	3.94 (2.31)	2.73 (3.62)	4.95 (3.41)	3.18 (3.50)	14.80 (12.84)
	RB-1	3.92 (2.41)	2.75 (3.68)	4.85 (3.73)	3.97 (3.94)	15.49 (13.76)

*Estimated
N.D. - No data

event. Excluding this event, the summer totals would have the same pattern as spring.

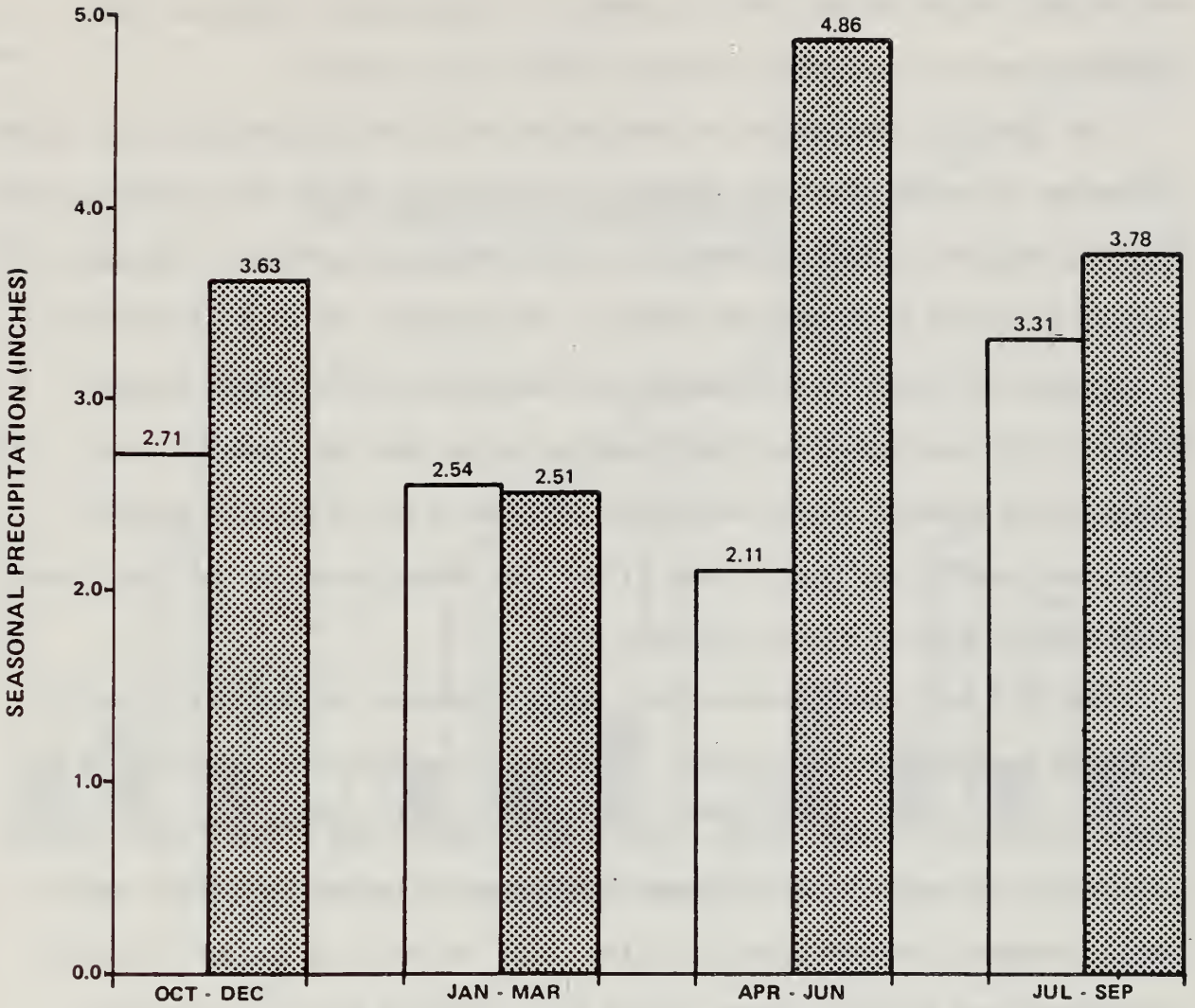
The Asphalt Wash gauges (RS-10 and RS-11) follow the defined pattern on an annual basis and during each season except the fall. This appears to be the case in all drainages which have a gauge close to the White River. The exact cause for this is unknown at this time.

Evacuation Creek presented the least correlation with the predicted pattern. Only on an annual basis and during the summer and winter seasons was the pattern evident. During the fall and spring an inverse pattern was noted. However, the total difference for these seasons was only 0.02 and 0.10 inches, respectively. The low adherence to the pattern may in part, be due to gauge locations. Gauge RV-8 is located near the drainage centerline while gauge RB-1 more than a mile east of Evacuation Creek. This conclusion is only speculative at this time and warrants further investigation.

Plant Site Wash contains two gauges within its confines (ARA-1) and ARA-13). However, at one station eight months of data required estimation. Therefore, nearby station RA-4, while not in the basin, was also included in the drainage analysis. On both a seasonal and an annual basis, the expected pattern occurred. It should be noted that during the fall season, ARA-13 reported a total 0.01 inches greater than RA-2. But this is not a significant deviation and may be the result of factors as yet unconsidered. Missing data for ARA-1 required estimation of each season except summer, but it is felt that the estimates presented are adequate and reasonable for this analysis.

Subsequent to the above analysis of 1984 data, a check of the above assumptions was made by conducting the same analysis of 1983 data. The results of this check are also presented, in parentheses, in Table 6.4-1. The 1983 pattern was similar to the 1984 pattern with two exceptions in Southam Canyon Wash. Gauge RA-4 reported the lowest seasonal total for the Southam Canyon gauges during the summer of 1983. This again may have been the result of thunderstorm activity or an unidentified problem with the gauge. Gauge RS-13 showed a significant deviation from the expected pattern during this period. Review of Southam Canyon's topography revealed that a ridgeline that cuts across the canyon between gauges RS-13 and ARA-2 may cause the observed variations from the expected pattern. The ridge may in effect divide Southam Canyon into two distinct basins. The effect on precipitation patterns would be most pronounced during period of high atmospheric instability, for example, during the summer when convective heating is at its peak. The data show large deviations from the expected pattern during late spring, summer and early fall.

The historic seasonal precipitation totals and seasonal statistics for 1984 are presented in Figure 6.4-3. Winter was the driest season, accumulating 2.51 inches (17.0 percent on the annual total) which is nearly identical to the previous six year mean of 2.54 inches. Fall and summer each accounted for approximately 25 percent of the annual total with 3.63 and 3.78 inches being collected, respectively. Both seasons were above the previous six year mean; with fall having the larger percent increase (33.9 percent) and summer a moderate increase (14.2 percent). Spring was



	FALL	WINTER	SPRING	SUMMER
1984 STANDARD DEVIATION	0.38	0.29	0.30	0.60
1984 RANGE	1.24	0.88	0.90	1.83
PERCENT OF ANNUAL TOTAL	24.5	17.0	32.9	25.6
PERCENT OF 6 YEAR MEAN	133.9	98.8	230.3	114.2

LEGEND

1984 SEASONAL AVERAGES

1978 - 1983 SEASONAL AVERAGES

TRACT AVERAGE
SEASONAL PRECIPITATION

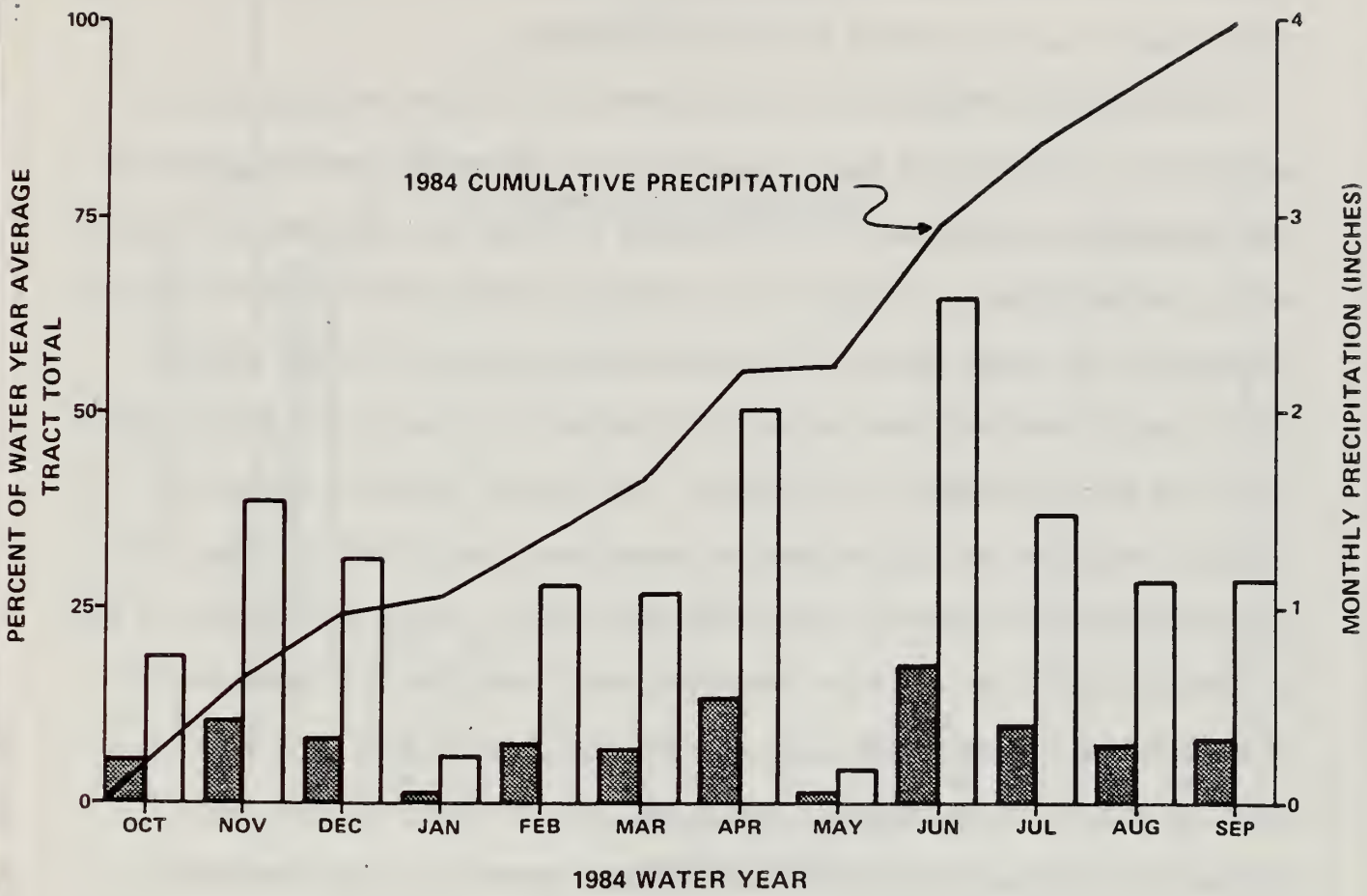
FIGURE 6.4-3

the wettest season with a tract average of 4.38 inches, which was 230 percent above the preceding six year mean of 2.11 inches.

The spatial distribution of precipitation varied seasonally, due to the influences of storm type and strength. During the winter and spring a tract standard deviation of approximately 0.30 inches was exhibited with both seasons reporting a range 0.90 inches. This appears to be a direct result of the type of precipitation events that occurred during these seasons. A review of the available NOAA data gave evidence that the seasons were dominated by synoptic scale events which tend to be relatively uniform. These events affected most if not all of the Uinta Basin to the same general extent and at approximately the same time.

The fall and summer seasons had higher standard deviations (0.38 and 0.60) and ranges (1.24 and 1.83), with similar accumulated totals of 3.63 and 3.78 inches, respectively. Unlike previous years, these seasons showed an increase in synoptic scale storm systems which helped to reduce variations. However, thunderstorm activity which occurred in conjunction with and between the synoptic storms, kept both standard deviation and range values for these seasons relatively high.

The monthly precipitation averages for the tracts are presented in Figure 6.4-4. Although generally higher in previous years, the month of May produced the lowest monthly mean of 0.19 inches, followed by January (the normal low month) which received 0.25 inches. The greatest monthly average of 2.59 inches occurred in June. April reported the second highest monthly average with 2.02 inches. The remaining months received between 0.77 and 1.55 inches, with four months clustered around 1.12 inches. The monthly



LEGEND

CUMULATIVE PRECIPITATION (PERCENT)

AVERAGE MONTHLY TOTAL (PERCENT)

AVERAGE MONTHLY TOTAL (INCHES)

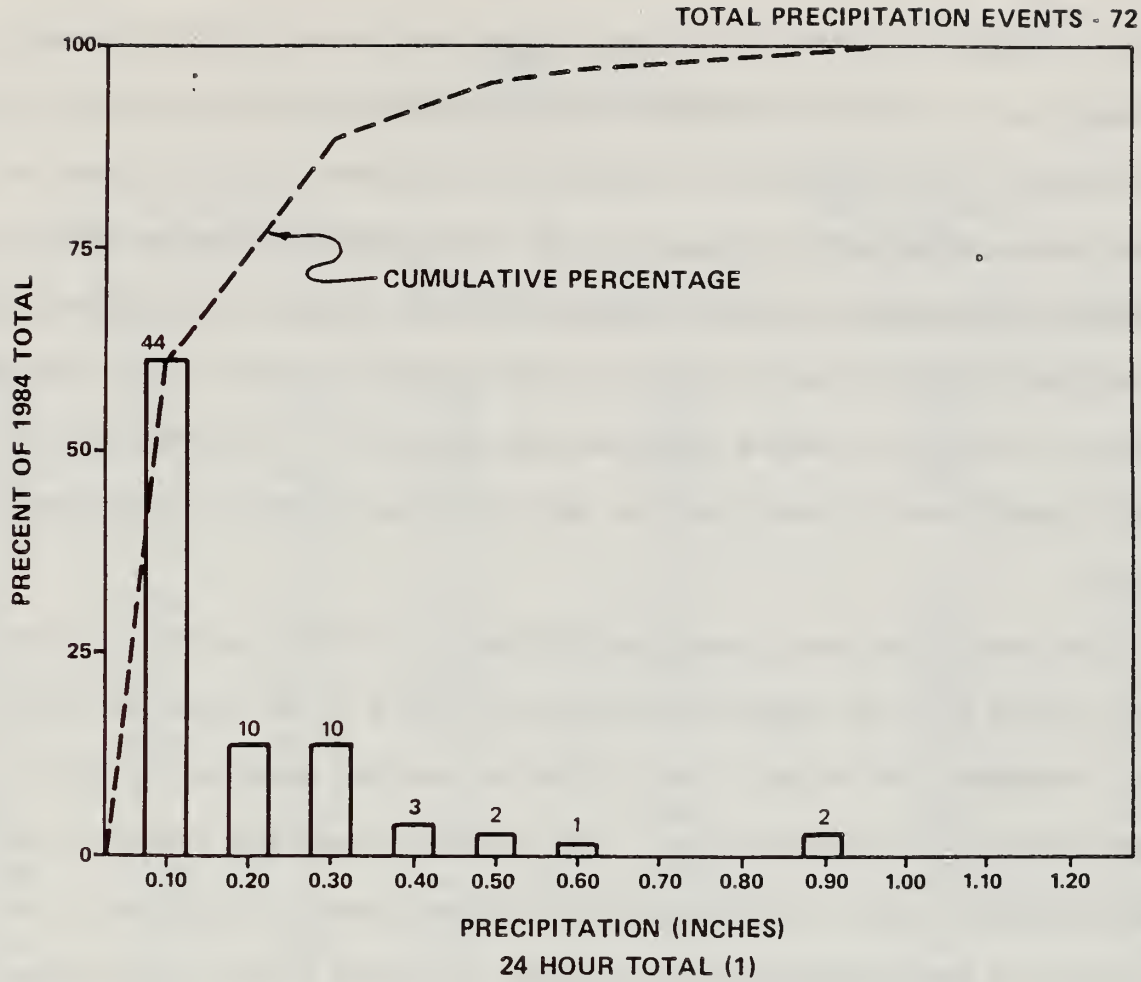
TRACT AVERAGE
MONTHLY PRECIPITATION

FIGURE 6.4-4

distribution of precipitation depicted in Figure 6.4-4 is typical of a semi-arid climate, such as exists in the Uinta Basin.

Precipitation frequencies were determined from the two gauges, ARA-1 and ARA-13, in Plant Site Wash. Analysis from these two stations indicate that measurable precipitation (0.10 inches or more) was received on 72 days during the water year. Figure 6.4-5 presents a tabulation of precipitation frequencies for these gauges. The most intense events in terms of equivalent hourly rainfall rate occurred on February 1, June 6 and June 7 when a rate of 0.80 inches/hour was recorded. Each event, however, lasted only 15 minutes, resulting in 0.20 inches of accumulated precipitation. The greatest precipitation events in Plant Site Wash were recorded on February 14 and on June 6-7, 1984 for six-hour duration events and June 6-7, 1984 for the 12 and 24-hour events. The 6, 12 and 24-hour event totals were 0.80, 1.10 and 1.40 inches, respectively. While the 24-hour event on June 6 and 7 matched the previous Plant Site Wash maximum event it is not considered unusual for the tract area, with a probable recurrence interval of approximately 2 years (VTN 1982b).

Seasonal and annual isohyetal analyses were performed and are reported in the 1984 Water Resources Field Data Report (Harmsworth Associates, 1985b). A tabulation of daily, monthly, seasonal and annual precipitation totals for WRSP sites may also be found in this report. Previous reports on the precipitation patterns of the project area have indicated that winter and early spring were dominated by synoptic-scale storms which affected the Uinta Basin on a relatively uniform basis. Late spring, summer and fall, while also having synoptic influences, were dominated by localized thunderstorms. The 1984 water year did not consistently follow this general



OBSERVED MAXIMUM PRECIPITATION AT ARA-13/ARA-1 (INCHES)

DURATION	INCHES	DATE
30 MIN	0.20	NUMEROUS
1 HOUR	0.30	NUMEROUS
2 HOUR	0.40	OCT 1/FEB 14/JUN 7
3 HOUR	0.60	JUN 7
6 HOUR	0.80	FEB 14 AND JUN 6-7
12 HOUR	1.10	JUN 6-7
24 HOUR (2)	1.40	JUN 6-7

LEGEND

(1) 24 HOUR PERIOD IS BASED ON CLOCK HOUR
ie. 0000 TO 2400

(2) 24 HOUR PERIOD HAS NO SPECIFIC START TIME
BUT MUST COVER 24 CONSECUTIVE HOURS

PRECIPITATION FREQUENCY
FOR ARA-13 AND ARA-1
1984 WATER YEAR

FIGURE 6.4-5

trend. Winter and spring continued to show the strong synoptic system influence as in the past. However, unlike earlier years, summer and fall also appear to be dominated by synoptic scale storms. This is shown in Table 6.4-2, where data collected by the three automatic gauges operated on the tracts are compared to the NOAA stations in the basin. Data presented on the table give an indication as to the synoptic nature of the 1984 summer storms. It should be noted that the NOAA stations all reported monthly totals significantly lower than the WRSP stations, which is considered normal.

The most significant precipitation event of 1984 occurred on June 5-8 when a total of 2.20 inches of rain fell at ARA-2, 2.30 inches at ARS-9, and ARA-1 received 2.00 inches. The single day maximum occurred during this storm period at all three gauges. The single day maximum totals for ARA-2, ARS-9 and ARA-1 were 1.10, 0.90 and 0.90 respectively (Table 6.4-2).

6.4.1.2 Pan Evaporation The second component of the 1984 hydrometeorologic monitoring program involved measurements of pan evaporation in the Plant Site Wash and Southam Canyon Wash drainages. This was accomplished through the use of a Class-A weather pan in Plan Site Wash (EVP-1) and a sunken, screened pan in Southam Canyon Wash (EVP-9). Evaporation pan data are intended to simulate the evaporative losses which would occur from open water surfaces, such as small lakes and reservoirs.

The measured evaporation data from pans EVP-1 and EVP-9 are presented in Table 6.4-3. Although the pans are of different construction, located in different drainages, and received different amounts of precipitation, the ration of their evaporations are fairly consistent month to month, with Plant Site Wash having the greater evaporative losses. Data for EVP-9

TABLE 6.4-2
DAILY PRECIPITATION FOR THE UINTA BASIN

	White River Precipitation Stations			NOAA Regional Stations		
Date	ARA-1/13	ARA-2	ARS-9	Vernal Airport	Roosevelt	Bonanza
4/9/84	0.10	--	--	0.02	0.01	--
4/10/84	0.30	0.40	0.30	0.02	0.05	--
4/18/84	0.20	--	0.20	0.04	--	--
4/19/84	0.20	0.10	0.20	0.07	0.05	--
4/20/84	0.60	0.60	0.70	0.01	--	0.65
4/25/84	0.40	0.50	0.50	0.06	--	--
6/5/84	0.30	0.30	0.40	0.37	0.06	0.08
6/6/84	0.50	0.50	0.60	0.12	0.21	0.62
6/7/84	0.90	1.10	0.90	0.42	0.08	0.10
6/8/84	0.30	0.30	0.40	0.12	0.01	1.10
6/20/84	0.10	0.20	0.40	--	0.04	0.23
7/9/84	--	0.10	0.10	0.09	0.20	0.35
7/10/84	0.40	0.50	0.50	0.25	--	0.36
7/22/84	0.10	--	--	0.24	0.25	--
7/23/84	0.10(1)	0.80	0.30	0.22	0.15	0.54
7/26/84	0.10	0.20	0.30	--	--	--
7/29/84	--	--	--	0.09	0.03	0.07
7/30/84	0.20	0.20	0.30	0.07	0.02	0.06
8/1/84	0.10	0.20	0.10	0.03	T	--
8/14/84	0.10	--	0.20	0.12	T	0.03
8/15/84	--	0.10	0.20	T	0.01	--
8/19/84	0.30	0.40	0.40	0.04	0.13	--
8/20/84	0.20	0.10	0.20	T	0.01	0.40
8/23/84	--	0.10	0.30	--	0.05	--
9/11/84	0.50	0.50	0.60	0.32	0.06	0.85(2)
9/20/84	0.10	--	0.10	0.02	0.07	--
9/24/84	0.10	0.20	0.20	0.30	0.10	--

--No precipitation recorded
T = Trace
(1) Actually 7/22 at 2345 hours
(2) Reported as 9/12/84

TABLE 6.4-3

PAN EVAPORATION FOR THE 1984 FREEZE-FREE PERIOD

	Plant Site Wash Station EVP-1		Southam Canyon Wash Station EVP-9		
Month	Date[1]	Evaporation (inches)	Date[1]	Evaporation (inches)	Ratio EVP-1/EVP-9
May	--	--	5/1-5/30	2.99	--
June	6/1-6/25	7.16	5/30-6/25	4.49	1.59
July	6/25-7/30	11.45	6/25-7/31	6.58	1.74
Aug	7/30-8/31	8.37	7/31-8/31	5.23	1.60
Sep	8/31-9/28	6.59	8/31-9/28	4.56	1.45
Oct	9/28-10/15	2.04	9/28-10/13	1.57[2]	1.30
TOTAL		35.61		22.43[3]	1.59

(1) Station EVP-1 began operation on 6/1/84; EVP-9 began operation on 5/1/84

(2) Estimated value. Actual evaporation determined from field data was 0.52 inches. This value appeared to be in error and was corrected.

(3) EVP-9 total includes June through October values only.

appeared to be in error for October 1984. Evaporation determined from the field data was 0.52 inches,which resulted in a station ration of 3.92. This far exceeded the freeze-free period ration (June through October) of 1.67. Review of the field data for the two stations indicated that the possible source of error was record keeping. Applying a correction to this evaporation value, resulted in a more reasonable station ration of 1.30 and a water loss of 1.57 inches. These values appear to be more consistent with the overall evaporation pattern.

A well-defined trend in evaporation can also be seen in Table 6.4-3. Both stations follow a pattern of rapidly increasing evaporation through May and June, reaching a peak in July, and showing a rapid decline thereafter. This pattern corresponds favorably with the annual solar cycle, under which the northern hemisphere receives ts greatest isolation during the same period. The variation in the st cion evaporation ratio also appears to follow this pattern, It can be edicted from this pattern that during the late fall, winter, and early spr ıg, when evaporation rates are at a minimum, the spatial variations across the tracts will approach zero.

6.4.2 Surface Water

The following discussion of program results and analysis for surface water data is divided into sections according to drainage basin. Each section presents specific discussions of streamflow and water quality.

Project-related activities during 1984 were entirely restricted to the Plant Site Wash drainage. Southam Canyon Wash, Asphalt Wash, and Evacuation Creek watersheds were not disturbed by project-related activities during the year. Of the surface water stations currently operated, only station 6602 in Plant Site Wash, Station 6700 on the White River downstream of the

tracts, and the Plant Site Wash, Station 6700 on the White River downstream of the tracts, and the Plant Site Retention Pond (RES-1) should be considered as potentially having been affected by construction activities. The remaining stations are still measuring background conditions unaffected by project activities.

Throughout this section, comparisons will be made between 1984 data and previous records. Generally, the entire period of record is used in comparisons for streamflow data. The baseline (pre-construction) period, 1975 through 1981, is commonly used for suspended sediment and water quality data comparisons. The rationale for this is that streamflow regimes (excluding that for Plant Site Wash) have not yet been notably affected by project activities. However, the analyses for suspended sediment and water quality data require that current-year data be compared to baseline data, as stipulated in the EMM.

Water resources data collected during 1984 were analyzed for possible project-related impacts by two general statistical procedures: 1) identification of outliers from the normal (baseline) range of values; and 2) determination of significant differences in water quality characteristics between control and treatment stations (if available). The statistical tests implemented and the limitations involved are the same as 1983 and were discussed in detail in the 1983 Annual Report (WRSOC 1984).

6.4.2.1 Evacuation Creek

A. Streamflow The 1984 water year marked the second consecutive year of well-above normal streamflow at Evacuation Creek station 6430. In fact, 1984 was the greatest year in total runoff for the 10-year period of record. Mean annual discharge for the 1984 water year was 12.7 cfs (9,202

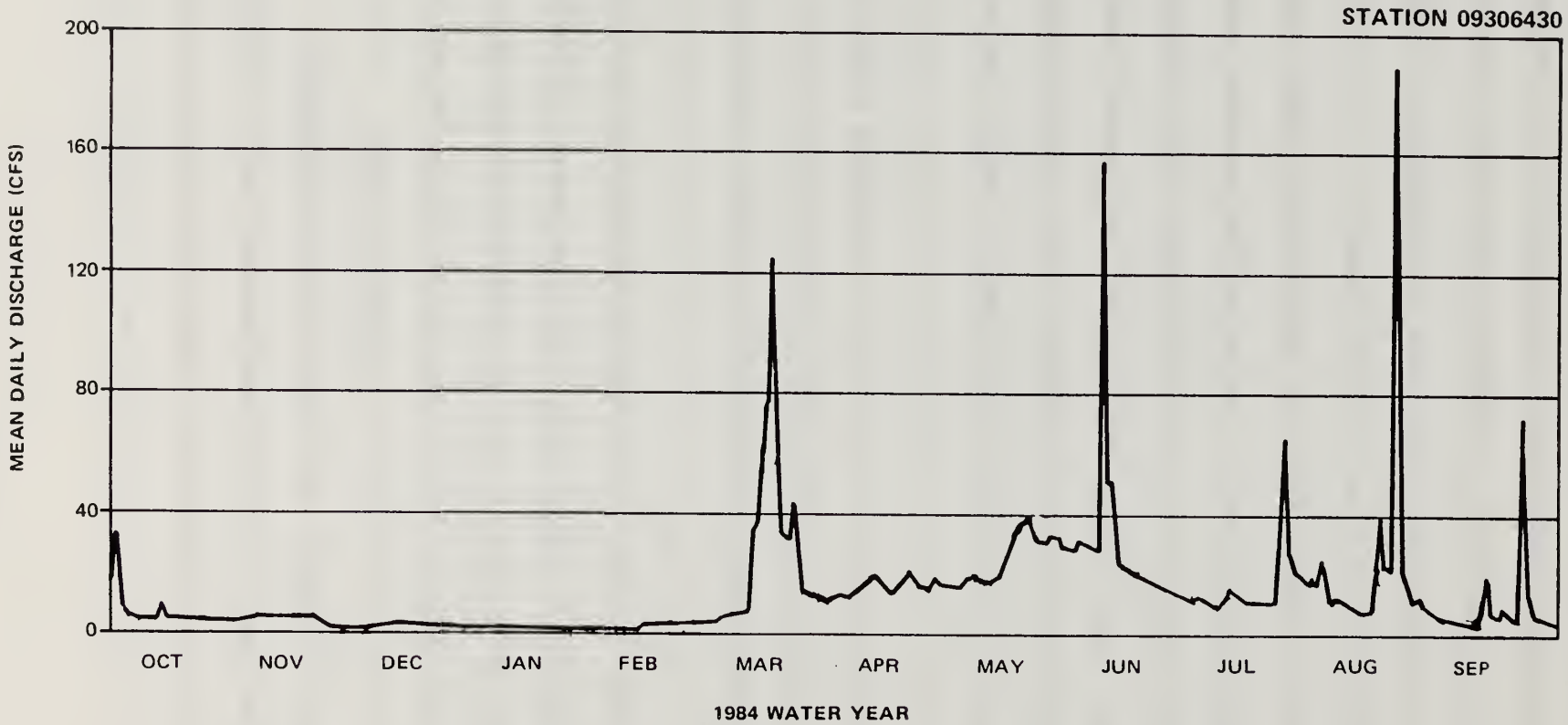
acre-feet) compared to the prior 9-year mean discharge of 2.80 cfs (2,027 acre-feet). As in the 1983 water year, the increased streamflow during 1984 was due to above normal snowmelt runoff and spring rainfall runoff from March through June. Also contributing to the high 1984 annual discharge were intense, scattered thundershowers from June to September. The 1984 hydrograph of Evacuation Creek is shown in Figure 6.4-6.

The baseflow period of October (1983) to mid-February (1984) recorded significantly higher mean monthly runoff than during the previous 9-year period. This was a carry over from the high 1983 runoff which continued into the 1984 water year. By February, however, the mean monthly flow (2.5 cfs) decreased substantially and was actually lower than the 9-year mean monthly value (5.3 cfs). This was probably due to the effects of intense fre ing.

The pe runoff period of the year occurred in June with a mean monthly flow of 27 s. This is greater than the 5.65 cfs normal for June (1975-1983) but it did not exceed the highest monthly mean of 45.0 cfs recorded in June 1983.

Thunderstorm activity in June, July, August and September contributed to the high summer month flows. Major peak flows (greater than 100 cfs) occurred on June 7, July 23, August 15, 16, 18, and 20 and September 21. The greatest peak flow for 1984 was 1320 cfs on August 20. This was within the previous maximum flow event of 1980 cfs recorded in 1979.

B. Water Quality Field water quality parameters of specific conductance, water temperature, pH, and dissolved oxygen were collected bi-weekly at Evacuation Creek during 1984. These field values are shown in Table 6.4-4.



1984 DISCHARGE HYDROGRAPH FOR
EVACUATION CREEK STATION 09306430

FIGURE 6.4-6

TABLE 6.4-4
FIELD WATER QUALITY DATA

EVACUATION CREEK STATION 09306430

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
10/06/83	1015	4.8	3350	11.0	8.0	9.5
10/21/83	1020	4.2	3610	3.8	8.9	11.2
11/04/83	0915	3.9	3460	4.3	7.2	10.0
11/14/83	1205	6.1	3510	7.0	7.8	9.6
12/02/83	0945	1.7	4060	4.5	7.8	9.8
12/27/83	1115	1.7	3800	6.0	8.3	10.0
01/04/84	1100	1.3	3590	7.0	7.8	9.6
01/26/84	1015	1.3	3900	7.0	8.0	9.7
02/02/84	1115	1.0	4100	8.0	7.2	9.6
02/23/84	1045	4.0	4360	4.0	8.8	10.7
03/05/84	1205	5.8	3840	4.0	8.4	10.1
03/14/84	1230	57	1150	0.0	9.2	11.6
03/26/84	1130	12	3280	5.0	8.2	10.2
04/11/84	1010	22	2980	5.8	7.3	10.0
04/23/84	0920	13	2560	7.8	8.2	9.4
05/07/84	1020	16	2900	6.0	8.6	10.0
05/16/84	0945	37	1980	9.8	8.3	9.2
05/24/84	0735	37	1810	13.5	8.0	8.3
06/13/84	1100	22	2360	15.0	8.3	8.0
06/27/84	1030	13	2900	17.5	8.4	8.4
07/09/84	1225	11	2550	24.0	7.8	8.0
08/17/84	0800	20	1710	16.0	7.8	8.2
08/28/84	0840	8.4	3070	14.0	8.7	--
09/10/84	0950	3.7	3370	13.0	8.5	8.3

Specific conductance field readings ranged from a low of 1150 micromhos/cm to a high of 4360 micromhos/cm. The low value of 1150 was recorded during the highest measured streamflow of 57 cfs. This trend of low conductivity during high streamflow has been documented in previous years (VTN 1976, 1977). The range of specific conductance readings is well within the recorded baseline range of 650 to 5,800 micromhos/cm. Water temperature values ranged from 0.0°C to 24.0°C and were within the baseline range (0.0°C to 33.5°C). Values of pH in 1984 ranged from 7.2 to 9.2 units. This range was within the baseline limits (7.0 to 9.8 units). Dissolved oxygen concentrations ranged from 8.0 mg/l to 11.6 mg/l. These values were also within the baseline range (4.6 to 14.5 mg.l).

Because no project activities occurred in Evacuation Creek during 1984, only a single laboratory water quality sample was collected to maintain continuity of the record (the radiochemical analysis sample was taken on a separate date). Laboratory water quality data collected in May 1984 are summarized in Table 6.4-5. The general water quality characteristics of Evacuation Creek have been discussed in previous WRSP reports (VTN 1976 and 1977) and will not be repeated here. Only variations in the water quality from previous trends are discussed.

Of the 53 laboratory parameters analyzed at Evacuation Creek during 1984, only suspended solids exceeded a previous maximum value. A suspended solids concentration of 23,300 mg/l exceeded the 1983 maximum of 1,940 mg/l. However, no baseline data were collected and only five previous analyses (all in 1983) have been collected. Analysis of the baseline records for suspended sediment, a closely related parameter, indicated that sediment

TABLE 6.4-5
LABORATORY WATER QUALITY DATA

FOR EVACUATION CREEK STATION 09306430

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PH, FIELD (UNITS)	PH, LAB (UNITS)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	SPECI-FIC CONDUC-TANCE LAB, UMHS@25
05/16/84	0945	37	9.8	9.2	8.3	8.1	15	9000	23300	1975	2240
05/24/84	0735	37	13.5	8.3	8.0	--	--	--	--	1807	--

DATE	TIME	TOTAL DISS SOLIDS, RESIDUE @ 180 C (MG/L)	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCARB (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS (MG/L AS N).
05/16/84	0945	1610	1686	619	331	288	1050	<1	12	8	<0.01
05/24/84	0735	--	--	--	--	--	--	--	--	--	--

DATE	TIME	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	NITRITE DISS (MG/L AS N)	NITRITE PLUS NITRATE DISS (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO DISS., (MG/L AS N)	SILICA, DISS., (MG/L AS SIO2)	CAL-CIUM, DISS., (MG/L)	MAGNE-SIUM, DISS., (MG/L)	SODIUM, DISS., (MG/L)	SODIUM ADSORP-TION RATIO
05/16/84	0945	18	<0.01	2.1	7.6	<0.01	14	101	89	306	5.4
05/24/84	0735	--	--	--	--	--	--	--	--	--	--

TABLE 6.4-5 (Continued...)
LABORATORY WATER QUALITY DATA

FOR EVACUATION CREEK STATION 09306430

DATE	TIME	PERCENT SODIUM	POTASSIUM, DISS., (MG/L)	SULFATE, DISS., (MG/L)	CHLORIDE, DISS., (MG/L)	FLUORIDE, DISS., (MG/L)	CYANIDE TOTAL (MG/L)	SULFIDE TOTAL (MG/L AS S)	BORON, DISS (UG/L)	ALUMINUM DISS (UG/L)	ARSENIC DISS., (UG/L)
05/16/84	0945	52	4.3	982	18	0.5	0.009	<0.2	440	45	2
05/24/84	0735	--	--	--	--	--	--	--	--	--	--

DATE	TIME	BARIUM, DISS., (UG/L)	BERYLLIUM, DISS., (UG/L)	CADMIUM DISS., (UG/L)	CHROMIUM, DISS., (UG/L)	COPPER DISS., (UG/L)	IRON DISS., (UG/L)	LEAD DISS., (UG/L)	MANGANESE, DISS.,	MERCURY	MOLYBDENUM, (UG/L)
05/16/84	0945	100	<5	<0.1	<1	<1	20	<1	<10	<0.1	13
05/24/84	0735	--	--	--	--	--	--	--	--	--	--

DATE	TIME	NICKEL, DISS., (UG/L)	SELENIUM DISS (UG/L)	SILVER, DISS., (UG/L)	STRONTIUM, DISS., (UG/L)	VANADIUM, DISS., (UG/L)	ZINC, DISS., (UG/L)	GROSS ALPHA DISS., (PCI/L AS U-NAT)	GROSS BETA DISS., (PCI/L AS CS-137)	GROSS BETA, DISS., (PCI/L AS SR90 /Y90)	RADIUM 226, DISS. RADON METHOD (PCI/L)
05/16/84	0945	<1	<1	<0.2	2600	2	53	--	--	--	--
05/24/84	0735	--	--	--	--	--	--	7.0	<10	<5	<0.50

values exceeding 100,000 mg/l often occurred during high flow (which was also occurring during 1984 sample collection).

Several parameters were detected below their respective minimum baseline range. These parameters included total dissolved solids, calcium, potassium, sodium, sulfide, beryllium, cadmium, chromium, lead, and strontium. The low values are probably due to natural variation and the high flow conditions during 1984.

6.4.2.2 Plant Site Wash The Plant Site Wash Station 6602 monitors local runoff from the small drainage area (0.08 square miles) below the retention dam. The total runoff during the 1984 water year was approximately 0.10 acre-feet. This runoff was recorded on October 2, 1983, and was the only documented flow event of the year.

Due to the sporadic nature of runoff in this drainage, no suspended sediment or water quality data were collected in 1984 at Station 6602.

6.4.2.3 Retention Dam Pond The monitoring program initiated in 1984 at the Retention Dam Pond was designed to provide information regarding the volume of water in the pond, the water quality characteristics, and (if possible) to determine subsurface leakage form the pond by conducting a water balance study. The Retention Dam was completed in September of 1983. By November 1983, ground water from the Birds Nest Zone in the mine shaft was being pumped (approximately 1 gallon per minute) into the Plant Site Wash channel. A portion of this drainage water flowed to the Retention dam and began to accumulate over the winter months. Although no records exists, it is estimated that less than 1 acre-foot of water was retained at the Dam form December 1983 to March 1984.

Weekly stage observations were initiated at the Retention Dam Pond (Designated as RES-1) beginning in early May 1984. The stage observations were converted to storage estimates (in acre-feet) by use of the stage-storage curve developed by Parsons Engineering. As shown in Table 6.4-6, the contents of the reservoir fluctuated in response to local runoff events. On May 8 the reservoir contained 1.9 acre-feet of water. A small portion of this water was probably derived from snowmelt runoff and rainfall runoff during March and April of 1984. A peak volume of 3.70 acre-feet was reached on July 10, resulting from several runoff events in June and early July. The volume of the reservoir gradually declined from evaporative losses for the remainder of the water year, reaching a low of 2.70 acre-feet on September 28.

Monthly field water quality measurements were also taken at station RES-1 beginning in May 1984 (see Table 6.4-6). The specific conductance readings during the year ranged from a low of 3130 micromhos on July 10 to a high of 4720 micromhos on September 12. An inverse relationship between the specific conductance and the reservoir contents was observed in 1984, with the lowest conductance value detected during the greatest storage volume of 3.70 acre-feet and the highest conductance observed with a volume of 2.80 acre-feet. This relationship was probably due to evaporative losses and a resultant concentration of dissolved ions. This pattern will likely continue, with a gradual buildup of dissolved salts and an increase in specific conductance over time.

Water quality samples were collected from RES-1 in May and July 1984 to characterize the water quality of the reservoir. The laboratory water quality results from these samples are presented in Table 6.4-7. In

TABLE 6.4-6

FIELD WATER QUALITY DATA
FOR THE RETENTION DAM POND (RES-1)

DATE	TIME	CONT-ENTS (ACRE-FEET)	GAGE HEIGHT, FEET ABV DATUM	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
05/08/84	0910	1.90	3.97	3310	12.0	6.8	9.5
05/29/84	0845	1.75	3.62	4440	19.0	7.8	8.6
06/11/84	1220	2.85	5.84	3130	17.0	8.6	12.2
07/02/84	1135	2.80	5.68	3400	25.5	8.6	10.4
07/10/84	0850	3.70	6.89	3130	22.0	8.4	7.0
07/19/84	0900	3.40	6.54	--	--	--	--
07/25/84	0935	3.30	6.39	3600	23.5	8.4	6.5
07/30/84	1120	3.20	6.29	--	--	--	--
08/06/84	1245	3.05	6.14	--	--	--	--
08/09/84	0938	3.00	6.07	--	--	--	--
08/13/84	1305	2.95	5.96	--	--	--	--
08/16/84	1215	2.90	5.90	4300	25.0	8.1	8.0
08/20/84	0845	2.90	5.89	--	--	--	--
08/27/84	1032	2.85	5.83	--	--	--	--
08/31/84	0820	2.80	5.75	--	--	--	--
09/04/84	0830	2.80	5.67	--	--	--	--
09/07/84	0938	2.70	5.60	--	--	--	--
09/10/84	1255	2.70	5.55	4220	19.0	8.6	8.8
09/12/84	0910	2.80	5.67	4720	19.0	8.9	8.6
09/17/84	1030	2.75	5.63	--	--	--	--
09/21/84	0910	2.75	5.61	--	--	--	--
09/28/84	0840	2.70	5.53	--	--	--	--

TABLE 6.4-7

LABORATORY WATER QUALITY DATA
FOR THE RETENTION DAM POND (RES-1) AND THE SUMP BELOW DAM (SUMP-1)

STATION NUMBER	DATE	TIME	WATER TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PH, FIELD (UNITS)	PH, LAB (UNITS)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)
RES-1	05/08/84	0910	12.0	9.5	6.8	8.3	--	--	14	3307
	05/29/84	0845	19.0	8.6	7.8	--	--	--	--	4436
	07/25/84	0950	22.5	6.5	8.4	7.8	50	18	12	3600
SUMP-1	07/25/84	1000	21.0	--	8.8	7.6	50	90	82	654

STATION NUMBER	DATE	TIME	SPECI-FIC CONDUC-TANCE LAB, UMHS@25	TOTAL DISS SOLIDS, RESIDUE @ 180 C (MG/L)	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCARB (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)
RES-1	05/08/84	0910	3810	2730	2793	600	467	133	--	--
	05/29/84	0845	--	--	--	--	--	--	--	--
	07/25/84	0950	3630	2950	3106	636	522	114	40	<1
SUMP-1	07/25/84	1000	700	510	446	105	0	200	110	<1

STATION NUMBER	DATE	TIME	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS (MG/L AS N)	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	NITRITE DISS (MG/L AS N)	NITRITE PLUS NITRATE DISS (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO DISS., (MG/L AS N)
RES-1	05/08/84	0910	18	--	0.03	0.30	<0.01	8.9	0.02	<0.01
	05/29/84	0845	--	--	--	--	--	--	--	--
	07/25/84	0950	22	26	<0.02	1.0	0.28	3.6	<0.01	<0.01
SUMP-1	07/25/84	1000	25	17	0.03	2.5	<0.01	0.09	0.13	<0.01

STATION NUMBER	DATE	TIME	SILICA, DISS., (MG/L AS SIO2)	CAL-CIUM, DISS., (MG/L)	MAGNE-SIUM, DISS., (MG/L)	SODIUM, DISS., (MG/L)	SODIUM ADSORP-TION RATIO	PERCENT SODIUM	POTAS-SIUM, DISS., (MG/L)	SUL-FATE, DISS., (MG/L)
RES-1	05/08/84	0910	9.0	120	73	680	12	71	2.8	16[illegible]
	05/29/84	0845	--	--	--	--	--	--	--	--
	07/25/84	0950	6.8	141	69	745	13	72	6.4	1900
SUMP-1	07/25/84	1000	34	37	3.0	105	4.5	61	32	136

TABLE 6.4-7 (Continued...)

LABORATORY WATER QUALITY DATA
FOR THE RETENTION DAM POND (RES-1) AND THE SUMP BELOW DAM (SUMP-1)

STATION NUMBER	DATE	TIME	CHLORIDE, DISS., (MG/L)	FLUORIDE, DISS., (MG/L)	CYANIDE TOTAL (MG/L)	SULFIDE TOTAL (MG/L AS S)	BORON, DISS (UG/L)	ALUMINUM DISS (UG/L)	ARSENIC DISS., (UG/L)	BARIUM, DISS., (UG/L)
RES-1	05/08/84	0910	160	0.5	--	--	470	--	--	--
	05/29/84	0845	--	--	--	--	--	--	--	--
	07/25/84	0950	175	0.6	0.005	<0.2	650	14	<1	<100
SUMP-1	07/25/84	1000	9.0	0.3	0.001	<0.2	210	37	16	<100

STATION NUMBER	DATE	TIME	BERYLLIUM, DISS., (UG/L)	CADMIUM DISS., (UG/L)	CHROMIUM, DISS., (UG/L)	COPPER DISS., (UG/L)	IRON DISS., (UG/L)	LEAD DISS., (UG/L)	MANGANESE, DISS., (UG/L)	MERCURY DISS (UG/L)
RES-1	05/08/84	0910	--	--	--	--	--	--	--	--
	05/29/84	0845	--	--	--	--	--	--	--	--
	07/25/84	0950	<5	<0.1	5	3	20	<1	<10	<0.1
SUMP-1	07/25/84	1000	<5	0.1	1	6	40	<1	<10	<0.1

STATION NUMBER	DATE	TIME	MOLYBDENUM, DISS., (UG/L)	NICKEL, DISS., (UG/L)	SELENIUM DISS (UG/L)	SILVER, DISS., (UG/L)	STRONTIUM, DISS., (UG/L)	VANADIUM, DISS., (UG/L)	ZINC, DISS., (UG/L)	GROSS ALPHA DISS., (PCI/L AS U-NAT)
RES-1	05/08/84	0910	--	--	--	--	--	--	--	--
	05/29/84	0845	--	--	--	--	--	--	--	26
	07/25/84	0950	22	3	5	<0.2	4400	9	12	--
SUMP-1	07/25/84	1000	11	2	<1	<0.2	780	10	15	6.0

STATION NUMBER	DATE	TIME	GROSS BETA DISS., (PCI/L AS CS-137)	GROSS BETA, DISS., (PCI/L AS SR90 /Y90)	RADIUM 226, DISS. RADON METHOD (PCI/L)	URANIUM DISS. DIRECT FLUORO-METRIC (PCI/L)
RES-1	05/08/84	0910	--	--	--	--
	05/29/84	0845	<10	<5	<0.50	48
	07/25/84	0950	--	--	--	--
SUMP-1	07/25/84	1000	12	<5	<0.50	--

general, the water quality of the reservoir was similar to the ground water from the Birds Nest Zone. This was as expected, since mine drainage pumped from the Birds Nest Zone, contributed substantially to the early storage of water in the reservoir. The reservoir water was a sodium-sulfate type with a TDS level of 2730 mg/l in May and 2950 mg/l in July.

Due to the organic-based grouting material used in sealing the Birds Nest Zone in the mine shaft and decline, which reached the pond into he mine drainage water, several organic constituents in the pond showed values greater than other tract waters. The total phenols concentration was 26 mg/l, dissolved organic carbon was 22 mg/l, and nitrite plus nitrate had a concentration of 8.9 mg/l.

The other constituents of the pond which displayed unusual values were the radiochemical parameters. Gross alpha had a value of 26 pci/l. Uranium was also analyzed and detected at 48 pci/l. The high levels of gross alpha and uranium were probably due to the contribution of Birds Nest water, which has been shown to have substantial radioactivity levels (VTN 1976, 1977).

Water was observed in the seepage collection pit below the Retention Dam during June and July of 1984. This water was sampled to determine its origin. This station was designated as SUMP-1 and the laboratory results are presented in table 6.4-7. This analysis verified that the water in the seepage pit was derived from local runoff surrounding the pit not from leakage through the dam. The TDS level of 510 mg/l and the sodium-bicarbonate character was more indicative of surface runoff than the pond water.

6.4.2.4 Southam Canyon Wash The total runoff from Southam Canyon Wash (station 6610 for the 1984 water year was 5.9 acre-feet. Approximately three quarters of this runoff (4.4 acre-feet) occurred from thunderstorms on

July 23 and July 25. The 1984 total annual runoff was well below the 9-year mean runoff of 30.0 acre-feet. However, because of the difficulties in monitoring streamflows from dry washes, several significant runoff events may not have been recorded in 1984 (see Field Data Report, Harmsworth Associates 1985b).

The maximum 1984 peak flow was 74 cfs on July 23. This event did not approach the peak of record of 440 cfs recorded in 1983.

Continuous specific conductance readings were recorded during each flow event, however, most readings were invalid due to silting. The maximum daily specific conductance reading was 1240 umhos/cm on July 23. This reading was within the range of baseline values observed at this station (33 to 2100 umhos/cm).

Due to the sporadic nature of runoff in Southam Canyon Wash, no water quality or suspended sediment samples were collected in 1984.

6.4.2.5 Asphalt Wash Streamflow data at Asphalt Wash station 6625, collected in previous years by the USGS, were collected by WRSOC during the 1984 water year. The total annual runoff of 19 acre-feet was very low compared to the 9-year average of 157 acre-feet/year. However, several flow events may not have been recorded in 1984. Maximum instantaneous flow during 1984 was 125 cfs recorded on July 24. This did not exceed the historic peak flow of 3680 cfs recorded in 1982. Collection of water quality and suspended sediment data at Asphalt Wash were not included in the 1984 monitoring program.

6.4.2.6 White River

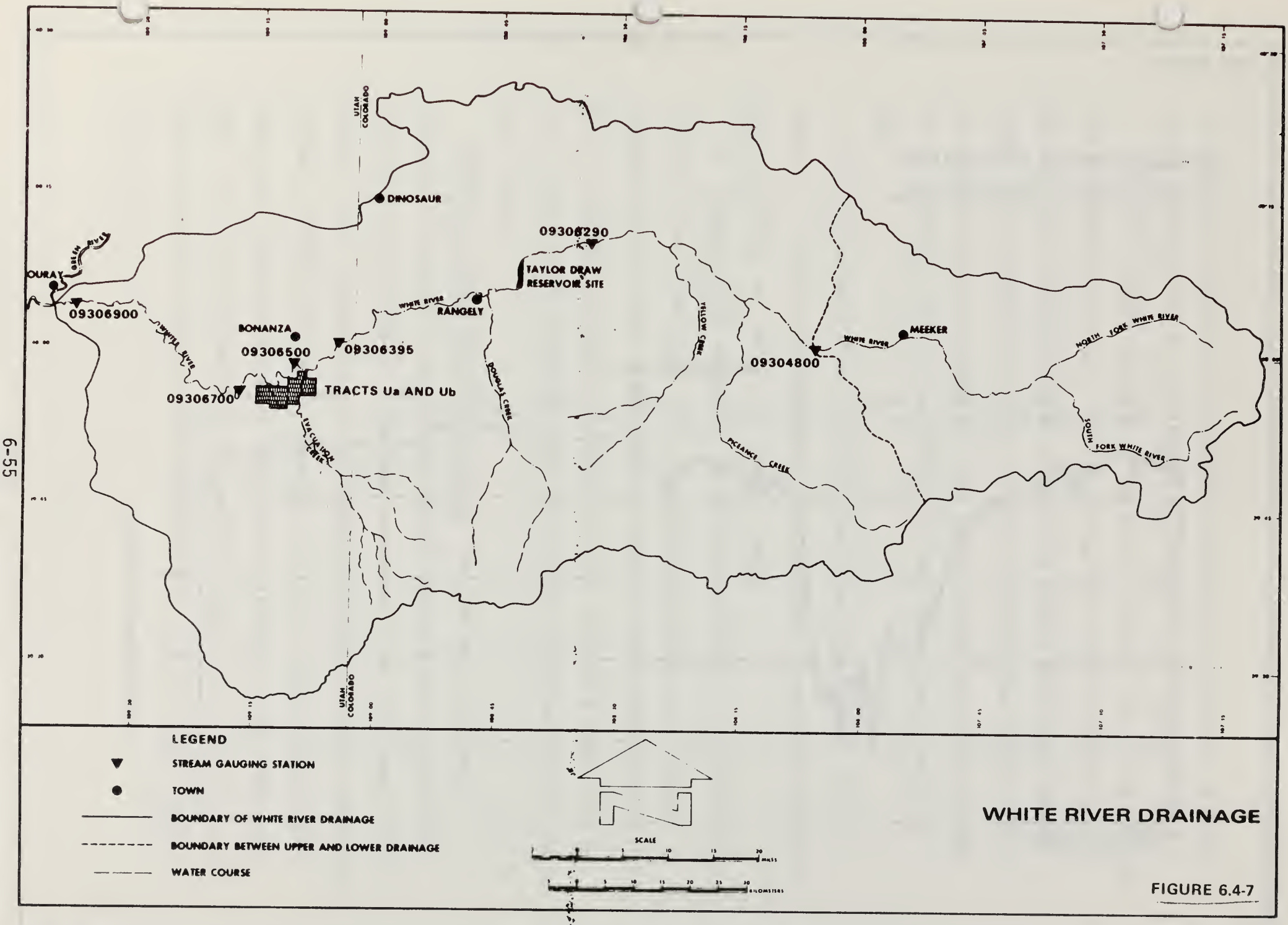
A. Streamflow During 1984 the White River recorded the second highest total runoff quality in the 61 year historic of stream gauging records on

the White River. The 1984 mean annual runoff for White River station 6700 (below Asphalt Wash) was 1355 cfs. Only the 1929 water year, with 1736 cfs (at Station 6500), had a greater mean annual runoff. The 1984 water year also marked the second consecutive high flow year, with the 1983 water year runoff of 1135 cfs ranking third highest overall. As in 1983, the 1984 high flows were derived primarily from an extremely heavy snowpack in the mountainous areas of the upper White River basin. The entire White River drainage and the boundary between upper and lower basins are shown in Figure 6.4-7.

The 1984 hydrograph of White River station 6700, as shown in Figure 6.4-8, illustrates the seasonal flow regime and can be used to depict the contributions of flow from the upper and lower basin. Upper basin baseflow occurred from October 1983 through February 1984. The periods of very low flow (less than 300 cfs) during December 1983 and January 1984 corresponded with severe freezing conditions. About March 10, 1984, flows began to rise rapidly as a result of an early thaw in the lower basin. This rising stage caused a breakup of the river's ice cover. This period of lower basin snowmelt runoff continued into June.

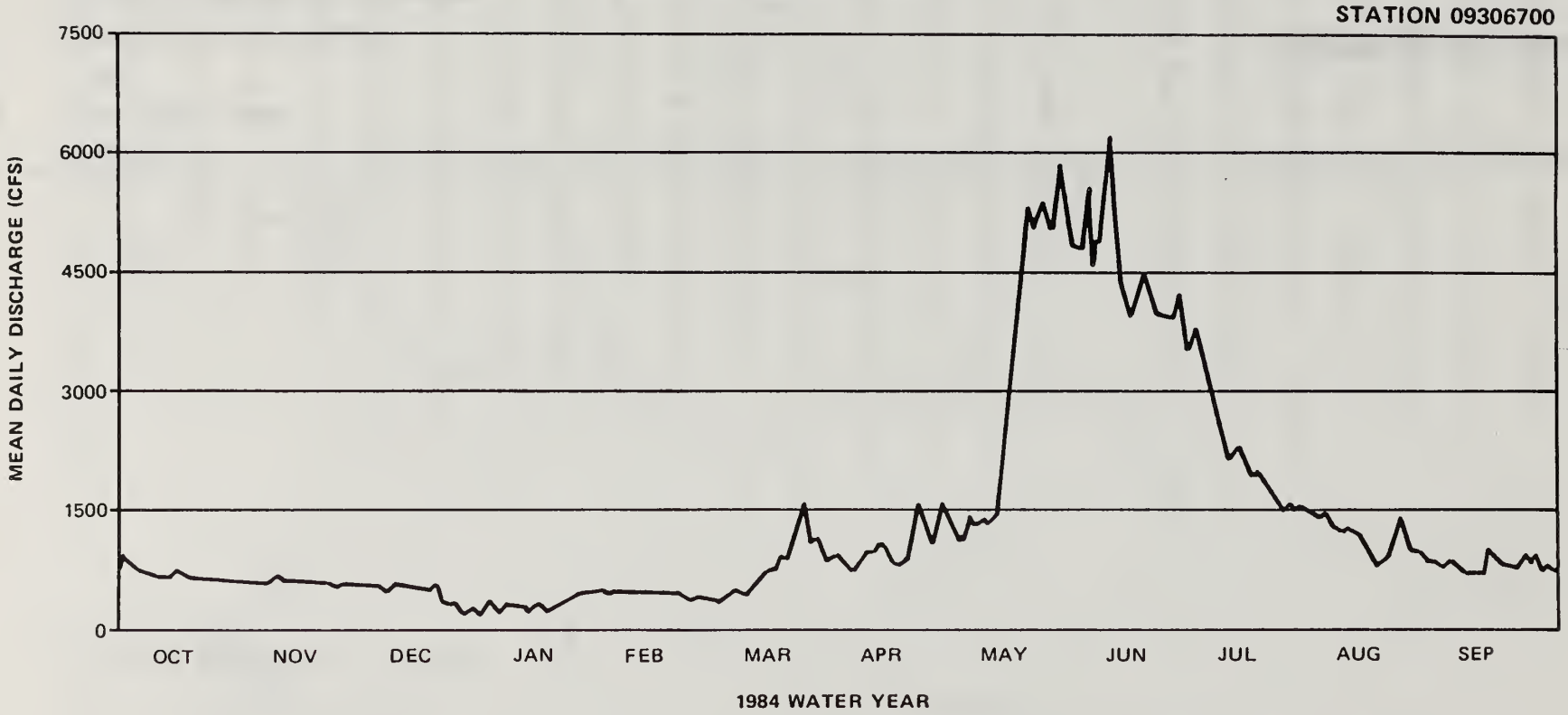
Upper basin high flow began about mid-May and persisted until early August. The unusually high magnitude and long duration of the upper basin high flow period were the result of an extremely heavy snowpack in the mountains. The peak snowmelt period occurred during early June.

The normal lower basin baseflow period during August and September was largely masked during 1984 because of the residual high baseflow from the upper basin. There were several days of lower basin high flow from July to September resulting from local thunderstorm runoff. Evacuation Creek and



WHITE RIVER DRAINAGE

FIGURE 6.4-7



1984 DISCHARGE HYDROGRAPH FOR
WHITE RIVER STATION 09306700

FIGURE 6.4-8

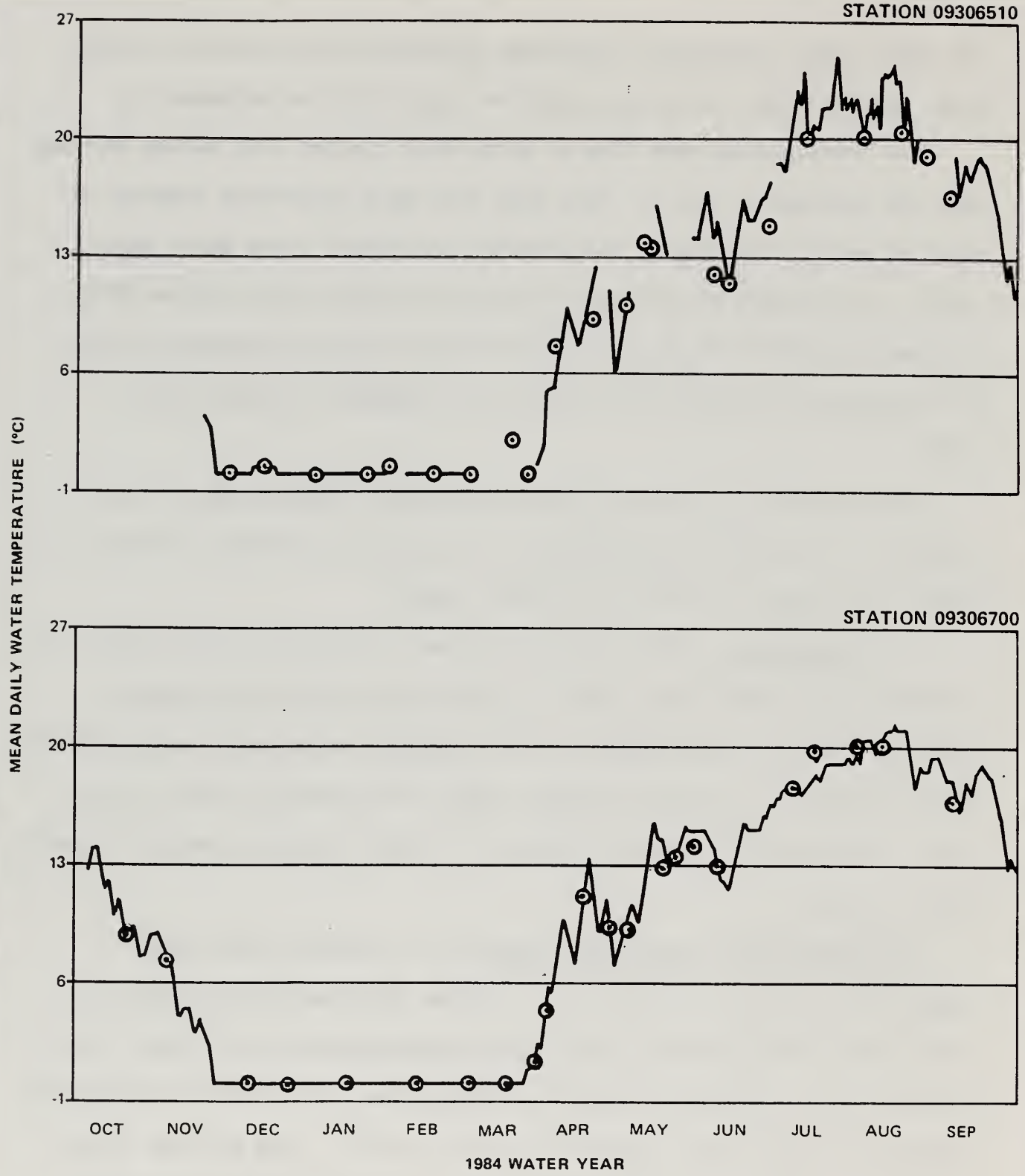
the other local tributaries contributed substantial storm runoff to White River station 6700 on July 23, August 16, August 20, and September 21.

The instantaneous peak flow of White River station 6700 during 1984 was 6420 cfs recorded on June 9. This peak flow has a recurrence interval of about 10 years, according to the Lindskov and Kimball Uinta Basin report (1982), which summarized 56 years of record for White River station 6500. This peak (although the greatest in the 10-year period of record at 6700) did not approach the peak flow of 8160 cfs recorded at Station 6500 in 1929.

The minimum daily flow at Station 6700 during 1984 was 181 cfs on January 1. This low flow corresponds to a recurrence interval of about 2.5 years, according to Lindskov and Kimball (1982).

B. Water Quality Water quality data was collected at four stations on the White River (6500, 6510, 6615, and 6700) during 1984 and included continuous (daily) water temperature and specific conductance records, field water quality data, suspended sediment data, and laboratory water quality data. The following discussion presents the 1984 results according to these general topics.

Continuous Water Temperature Records The 1984 mean daily water temperatures recorded at White River stations 6510 and 6700 are shown in Figure 6.4-9 (instantaneous temperature measurements are also shown). The mean daily water temperatures at 6510 ranged from 0.0°C to 25,0°C during the year and at station 6700 ranged from 0.0° to 21.5°C. Some periods of poor record were deleted from station 6510, due to siltation of the temperature probe. All valid 1984 mean daily temperature values on the White River were within the baseline range of Station 6700 (0.0 to 26.0°C). As in previous



LEGEND

⊙ INSTANTANEOUS VALUES

1984 WATER TEMPERATURE HYDROGRAPHS

FOR WHITE RIVER STATIONS 09306510 AND 09306700

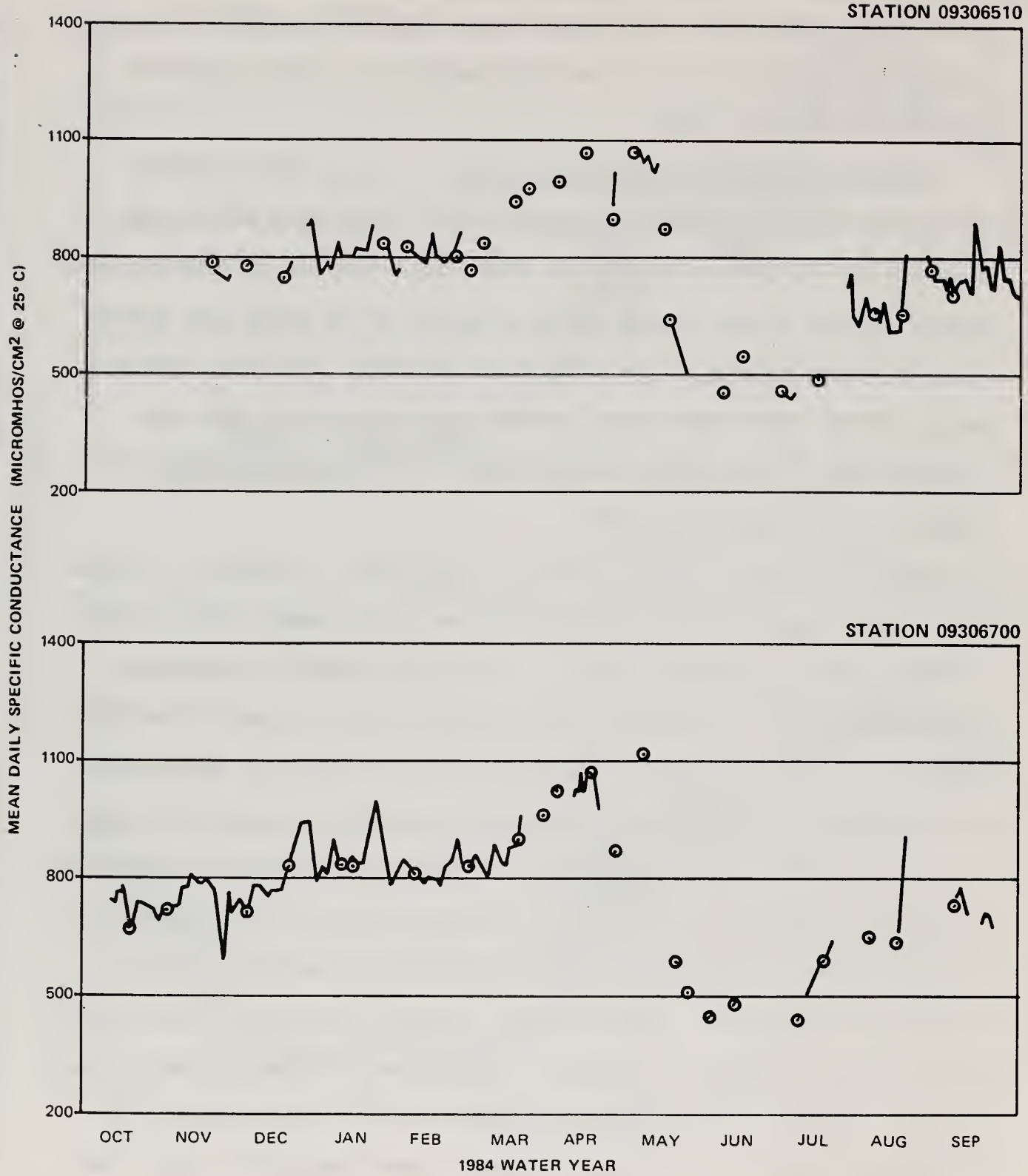
FIGURE 6.4-9

years, water temperature of the White River exhibited a pattern directly related to air temperature with an approximately 1 or 2 day lag period (Lindskov and Kimball 1982).

Continuous Specific Conductance Records The mean daily specific conductance values at White River station 6510 ranged from 435 to 1080 micromhos during 1984 and at Station 6700 ranged from 498 to 1080 micromhos. Several periods of poor record due to siltation of the probe were deleted from the record at both of the White River stations. All valid 1984 mean daily specific conductance values on the White River were within the baseline range (238 to 1400 micromhos) and within the 99% confidence interval (250 to 1183 micromhos).

As can be seen in the 1984 specific conductance hydrographs in Figure 6.4-10, the lowest values occurred during the peak snowmelt runoff period from the upper basin (May and June). The highest specific conductance values were generally recorded during the early spring snowmelt from the lower basin (March and April). Figure 6.4-10 also shows the instantaneous measurements of specific conductance taken at the White River during 1984.

A statistical comparison of the mean daily specific conductance records collected at Station 6510 and 6700 was limited because of the poor recovery of data in 1984. A total of 85 concurrent days were available for this statistical comparison. A paired t-test, comparing the mean values from the concurrent days of record, indicated a significant different at the 2% level ($P<0.02$). However, considering the accuracy of the field records ($\pm$ 11 micromhos), no substantiation can be given to this statistical test. The variation in specific conductance values between these stations is so low that is is indistinguishable from the instrument error.



LEGEND

⊙ INSTANTANEOUS VALUES

1984 SPECIFIC CONDUCTANCE HYDROGRAPHS

FOR WHITE RIVER STATIONS 09306510 AND 09306700

FIGURE 6.4-10

Field Water Quality Data Field water quality measurements taken at White River stations 6510 and 6615 during 1984 are listed in Table 6.4-8. Field values of pH ranged from 7.0 to 9.0 at Station 6510 and from 7.0 to 8.8 at Station 6615. These pH extremes are within the baseline range of pH measurements on the White River (6.0 to 9.4 units). Dissolved oxygen concentrations ranged from 7.2 to 10.8 mg/l at Station 6510 and from 7.0 to 11.5 mg/l at Station 6615. These extremes are within the baseline range of dissolved oxygen measurements for the White River (3.5 to 13,3 mg/l).

Suspended Sediment Data Collection of suspended sediment samples was restricted to White River stations with existing cableways (i.e., stations 6500 and 6700). Suspended sediment data collection was reduced to quarterly analyses in 1984 due to a lack of project activities which could affect the White River. These data are listed in Table 6.4-9. Suspended sediment levels ranged from 173 to 4,010 mg/l at Station 6500 and from 159 to 4080 mg/l at Station 6700. These values are well within the baseline range of Station 6700 (46 to 28,500 mg/l).

Laboratory Water Quality Data The laboratory water quality data collected in 1984 on the White River are listed in Table 6.4-10. The quarterly samples were scheduled to coincide with the following seasonal flow regimes: upper basin baseflow (taken in February), lower basin highflow (taken in April), upper basin highflow (taken in June), and lower basin baseflow (taken in September). Same day samples were collected at White River stations 6510 and 6615 for each of these periods, except for the February 28 sample, when Station 6700 was substituted for Station 6615 because it could not be reached due to heavy snowpack.

TABLE 6.4-8
FIELD WATER QUALITY DATA

FOR WHITE RIVER STATIONS 09306510 AND 09306615

STATION ID	DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
09306510	11/18/83	1100	E560	791	--	--	--
	01/25/84	0950	E430	930	0.0	8.8	--
	02/03/84	1125	E460	820	0.5	7.3	--
	02/20/84	1156	E440	803	0.0	8.6	--
	03/02/84	1200	E430	840	0.0	7.8	10.0
	03/21/84	1110	E1310	956	2.0	8.6	10.2
	03/26/84	0915	E1150	986	0.0	8.8	10.8
	04/06/84	1015	E790	998	7.9	7.6	9.8
	04/23/84	1115	E1160	905	9.4	8.2	9.4
	05/02/84	1019	E1100	1070	10.0	8.6	9.3
	05/11/84	0930	E1700	880	13.8	7.8	8.2
	05/15/84	1015	E4000	640	13.5	7.0	--
	06/04/84	0900	E4350	452	12.0	8.2	8.5
	06/11/84	1030	E4500	540	11.5	8.6	9.0
	06/27/84	0815	E3900	438	15.1	8.4	8.0
	07/09/84	1100	E3130	487	20.0	8.5	8.7
	08/03/84	1010	E1350	666	20.0	8.2	8.2
	08/16/84	0905	E890	660	20.5	9.0	7.2
	08/27/84	1058	E910	773	19.0	8.6	8.7
	09/04/84	0935	E770	700	16.5	9.0	8.8
09306615	11/03/83	0850	E590	720	7.5	8.1	9.6
	11/15/83	0840	E600	743	3.5	8.5	10.6
	12/05/83	1300	E545	735	0.0	7.8	11.0
	12/19/83	1045	E470	825	0.0	7.7	11.1
	01/12/84	1315	E300	820	0.0	8.2	11.2
	02/07/84	1000	E480	825	0.0	7.2	11.0
	03/27/84	1150	E910	960	1.0	8.1	11.5
	04/02/84	1305	E760	1050	5.0	7.8	10.3
	04/16/84	1245	E820	1090	12.0	7.8	9.0
	04/25/84	1030	E1110	870	9.6	8.2	9.4
	05/03/84	1140	E1190	1070	9.6	8.1	9.2
	05/18/84	0955	E5100	580	13.2	8.0	8.2
	05/23/84	1050	E5300	510	13.8	8.2	8.4
	05/30/84	1000	E4900	450	14.2	8.2	8.3
	06/04/84	1200	E4450	468	13.5	8.0	8.5
	07/03/84	1120	E3100	448	18.5	8.1	7.8
	07/16/84	0920	E1900	592	20.0	8.1	9.2
	08/01/84	1145	E1360	640	21.0	8.8	7.0
	08/13/84	1100	E1000	593	22.0	7.0	9.2
	09/04/84	1215	E830	696	18.0	8.8	8.0

TABLE 6.4-9

SUSPENDED SEDIMENT DATA

FOR WHITE RIVER STATIONS 09306500 AND 09306700

STATION NUMBER	DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)	WATER TEMPER-ATURE (DEG C)
09306500	02/29/84	1100	383	173	179	0.0
	04/17/84	0950	891	1950	4691	9.5
	06/06/84	0950	4810	4010	52078	11.0
	09/05/84	0950	795	272	584	17.0
09306700	02/29/84	1330	340	159	146	0.0
	04/17/84	1300	826	2560	5709	12.0
	06/06/84	1355	4820	4080	53097	13.0
	09/05/84	1330	783	263	556	17.2

TABLE 6.4-10
LABORATORY WATER QUALITY DATA

FOR WHITE RIVER STATIONS 09306510, 09306615 AND 09306700

STATION NUMBER	DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PH, FIELD (UNITS)	PH, LAB (UNITS)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)
09306510	02/28/84	1000	E380	0.0	10.0	7.2	7.7	10	41	90
	04/16/84	0915	E770	9.0	9.4	8.0	8.3	--	--	1500
	06/04/84	0900	E4350	12.0	8.5	8.2	7.7	25	1200	2200
	09/04/84	0935	E770	16.5	8.8	9.0	8.3	--	--	292
09306615	04/16/84	1245	E820	12.0	9.0	7.8	8.3	--	--	1650
	06/04/84	1200	E4450	13.5	8.5	8.0	7.8	22	1400	2720
	09/04/84	1215	E830	18.0	8.0	8.8	8.2	--	--	294
09306700	02/28/84	1315	E380	0.0	10.0	7.2	7.8	--	--	80

STATION NUMBER	DATE	TIME	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	SPECI-FIC CONDUC-TANCE LAB, UMHS@25	TOTAL DISS., SOLIDS, RESIDUE @ 180c (MG/L)	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCAR. (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)
09306510	02/28/84	1000	776	860	545	554	324	121	203	6.0
	04/16/84	0915	1070	1160	800	807	443	211	232	--
	06/04/84	0900	452	470	345	313	191	59	132	200
	09/04/84	0935	700	620	510	480	278	87	191	--
09306615	04/16/84	1245	1090	1180	815	830	447	215	232	--
	06/04/84	1200	468	490	330	287	188	60	128	190
	09/04/84	1215	696	600	505	481	283	92	191	--
09306700	02/28/84	1315	820	860	545	553	331	128	203	--

E = Estimated

TABLE 6.4-10 (Continued...)
LABORATORY WATER QUALITY DATA

FOR WHITE RIVER STATIONS 09306510, 09306615 AND 09306700

STATION NUMBER	DATE	TIME	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS., (AS N) (MG/L)	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	NITRITE DISS., (MG/L AS N)	NITRITE PLUS NITRATE DISS., (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)
09306510	02/28/84	1000	<1	2.1	<2	<0.01	0.10	<0.01	0.36	<0.01
	04/16/84	0915	--	8.3	--	<0.01	2.5	0.05	1.2	3.4
	06/04/84	0900	<1	5.5	4	<0.01	0.90	<0.01	0.63	2.3
	09/04/84	0935	--	5.0	--	<0.02	0.20	<0.01	0.57	0.27
09306615	04/16/84	1245	--	8.1	--	0.17	2.5	0.04	0.92	3.4
	06/04/84	1200	<1	8.5	<5	0.15	2.5	<0.01	0.51	3.0
	09/04/84	1215	--	5.0	--	<0.02	0.20	<0.01	0.53	0.29
09306700	02/28/84	1315	--	2.4	--	<0.01	0.10	<0.01	0.35	<0.01

STATION NUMBER	DATE	TIME	PHOS-PHORUS, ORTHO DISS., (AS P) (MG/L)	SILICA, DISS., (MG/L AS SIO2)	CAL-CIUM, DISS., (MG/L)	MAGNE-SIUM, DISS., (MG/L)	SODIUM, DISS., (MG/L)	SODIUM ADSORP-TION RATIO	PERCENT SODIUM	POTAS-SIUM, DISS., (MG/L)
09306510	02/28/84	1000	0.01	16	77	32	65	1.6	30	2.6
	04/16/84	0915	0.41	15	95	50	108	2.2	34	5.5
	06/04/84	0900	1.0	10	45	19	28	0.88	24	1.5
	09/04/84	0935	0.01	16	62	30	49	1.3	28	1.5
09306615	04/16/84	1245	0.87	15	95	51	111	2.3	35	5.4
	06/04/84	1200	0.88	11	44	19	28	0.89	24	1.6
	09/04/84	1215	<0.01	16	64	30	51	1.3	28	1.8
09306700	02/28/84	1315	<0.01	16	78	33	63	1.5	29	2.4

TABLE 6.4-10 (Continued...)
LABORATORY WATER QUALITY DATA

FOR WHITE RIVER STATIONS 09306510, 09306615 AND 09306700

STATION NUMBER	DATE	TIME	SUL-FATE, DISS., (MG/L)	CHLOR-IDE, DISS., (MG/L)	FLUOR-IDE, DISS., (MG/L)	CYANIDE TOTAL (MG/L AS CN)	SULFIDE TOTAL (MG/L AS S)	BORON, DISS., (UG/L)	ALUM-INUM DISS., (UG/L)	ARSENIC DISS., (UG/L)
09306510	02/28/84	1000	224	16	0.3	<0.001	<0.2	110	23	<1
	04/16/84	0915	367	31	0.3	--	--	210	--	--
	06/04/84	0900	119	11	0.4	<0.001	<0.2	100	25	<1
	09/04/84	0935	196	10	0.3	--	--	120	--	--
09306615	04/16/84	1245	383	34	0.3	--	--	220	--	--
	06/04/84	1200	99	8.0	0.2	<0.001	<0.2	90	20	<1
	09/04/84	1215	194	10	0.3	--	--	120	--	--
09306700	02/28/84	1315	224	15	0.3	--	--	90	--	--

STATION NUMBER	DATE	TIME	BARIUM, DISS., (UG/L)	BERYL-LIUM, DISS., (UG/L)	CADMIUM DISS., (UG/L)	CHRO-MIUM, DISS., (UG/L)	COPPER DISS., (UG/L)	IRON DISS., (UG/L)	LEAD DISS., (UG/L)	MAN-GANESE, DISS., (UG/L)
09306510	02/28/84	1000	<100	<5	0.1	1	2	<10	4	10
	04/16/84	0915	--	--	--	--	--	--	--	--
	06/04/84	0900	<100	<5	<0.1	<1	1	40	<1	10
	09/04/84	0935	--	--	--	--	--	--	--	--
09306615	04/16/84	1245	--	--	--	--	--	--	--	--
	06/04/84	1200	<100	<5	<0.1	<1	2	40	<1	10
	09/04/84	1215	--	--	--	--	--	--	--	--
09306700	02/28/84	1315	--	--	--	--	--	--	--	--

TABLE 6.4-10 (Continued...)
LABORATORY WATER QUALITY DATA

FOR WHITE RIVER STATIONS 09306510, 09306615 AND 09306700

STATION NUMBER	DATE	TIME	MERCURY DISS., (UG/L)	MOLYB-DENUM, DISS., (UG/L)	NICKEL, DISS., (UG/L)	SELE-NIUM DISS., (UG/L)	SILVER, DISS., (UG/L)	STRON-TIUM, DISS., (UG/L)	VANA-DIUM, DISS., (UG/L)	ZINC, DISS., (UG/L)
09306510	02/28/84	1000	<0.1	<1	2	<1	<0.2	970	2	28
	04/16/84	0915	--	--	--	--	--	--	--	--
	06/04/84	0900	<0.1	3	2	<1	<0.2	470	2	9
	09/04/84	0935	--	--	--	--	--	--	--	--
09306615	04/16/84	1245	--	--	--	--	--	--	--	--
	06/04/84	1200	<0.1	3	1	<1	<0.2	460	1	14
	09/04/84	1215	--	--	--	--	--	--	--	--
09306700	02/28/84	1315	--	--	--	--	--	--	--	--

STATION NUMBER	DATE	TIME	GROSS ALPHA DISS., (PCI/L AS U-NAT)	GROSS BETA DISS., (PCI/L AS CS-137)	GROSS BETA, DISS., (PCI/L AS SR90 /Y90)
09306510	02/28/84	1000	--	--	--
	04/16/84	0915	--	--	--
	06/04/84	0900	<2.0	<10	<5.0
	09/04/84	0935	--	--	--
09306615	04/16/84	1245	--	--	--
	06/04/84	1200	2.0	<10	<5.0
	09/04/84	1215	--	--	--
09306700	02/28/84	1315	--	--	--

The relative contributions of major anions and cations according to the flow regime have been discussed in detail in previous WRSP reports (VTN 1976, 1977, and WRSOC 1983). During 1984, three of the four major flow regimes were represented by the quarterly samples collected. Figure 6.4-11 shows a comparison of the normal baseline ion contributions to the 1984 results by use of stiff diagrams.

The February 28 sample was representative of the upper basin baseflow period, with water characteristically high in calcium, bicarbonate, and a medium TDS level. The April 16 sample was representative of the lower basin highflow period, being characterized by increased sodium and sulfate concentrations and a high TDS level. The June 4 sample was characteristic of the upper basin highflow period, with low contributions of calcium, bicarbonate, and TDS. The lower basin baseflow period normally observed in August and September was somewhat masked in 1984 by the carry over of highflows from the upper basin. This lower basin baseflow period, normally high in sodium, sulfate, and TDS levels, was more characteristic of the upper basin baseflow period in 1984, showing higher contributions of calcium and bicarbonate and medium TDS concentration.

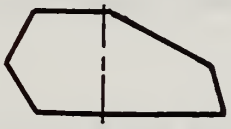
Several water quality parameters collected in 1984 surpassed the baseline range of values. The April water quality parameters which exceeded baseline maximums included calcium, magnesium, sulfate, alkalinity, total hardness, noncarbonate hardness, ammonia, nitrite, nitrite plus nitrate, orthophosphorus, and boron. These high concentrations are attributed to the contribution of lower basin runoff (i.e., Evacuation Creek), which is commonly high in these constituents. Also, the June sample showed unusually high values for suspended solids and chemical oxygen demand. These

STATION NO. 09306510

1984 WATER YEAR

UPPER BASIN BASEFLOW

FEBRUARY 28



545

LOWER BASIN HIGHFLOW

APRIL 16

800

UPPER BASIN HIGHFLOW

JUNE 4

345

LOWER BASIN BASEFLOW

SEPTEMBER 4

510

WHITE RIVER STATION NOS.
09306395 THROUGH 09306900
1975 – 1979 WATER YEARS

UPPER BASIN BASEFLOW

521

LOWER BASIN HIGHFLOW

708

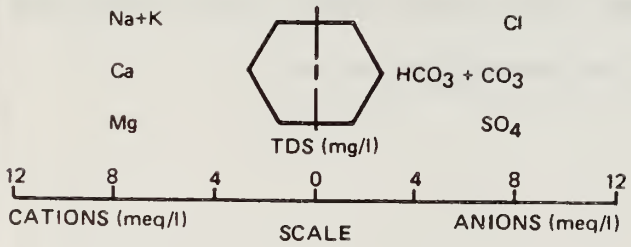
UPPER BASIN HIGHFLOW

295

LOWER BASIN BASEFLOW

737

LEGEND



DISTRIBUTION OF MAJOR IONS
DURING DIFFERENT FLOW
REGIMES AT WHITE RIVER

FIGURE 6.4-11

exceedances are attributed to the high flows associated with upper basin runoff. All of these high values in 1984 were detected at both the upstream station (6510) and the downstream (6615 or 6700) stations and, therefore, are believed to be due to natural variations or from project activities nor related to the WRSP.

The concurrent water quality data collected from White River Stations 6510 and 6615) were compared statistically for significant differences using a paired-replicates test and the Mann-Whitney U test. Results of these tests for each of the parameters collected on a quarterly basis, showed no significant differences (P>0.05) between stations.

6.4.3 Ground Water

The results and analyses of the ground water monitoring program are presented in order according to hydrostratigraphic units; namely the Birds Nest Zone in the Green River Formation, Uinta Formation, Southam Canyon alluvium, and six individual zones for the retention dam wells. Discussion of each of these ground water units is further separated into water level and water quality sections.

6.4.3.1 Birds Nest Zone (Green River Formation Ground water conditions in the Birds Nest Zone were monitored at ten wells. The wells include P-1, P-2 Lower, P-3, G-5, G-8A, G-10, G-11, G-14, G-15 and G-21.

A. Water Levels Water level data are presented separately for P-wells and G-wells, followed by a brief summary of findings.

P-wells The annual extreme and mean daily static water levels recorded at well P-1 during the 1984 water year are summarized below.

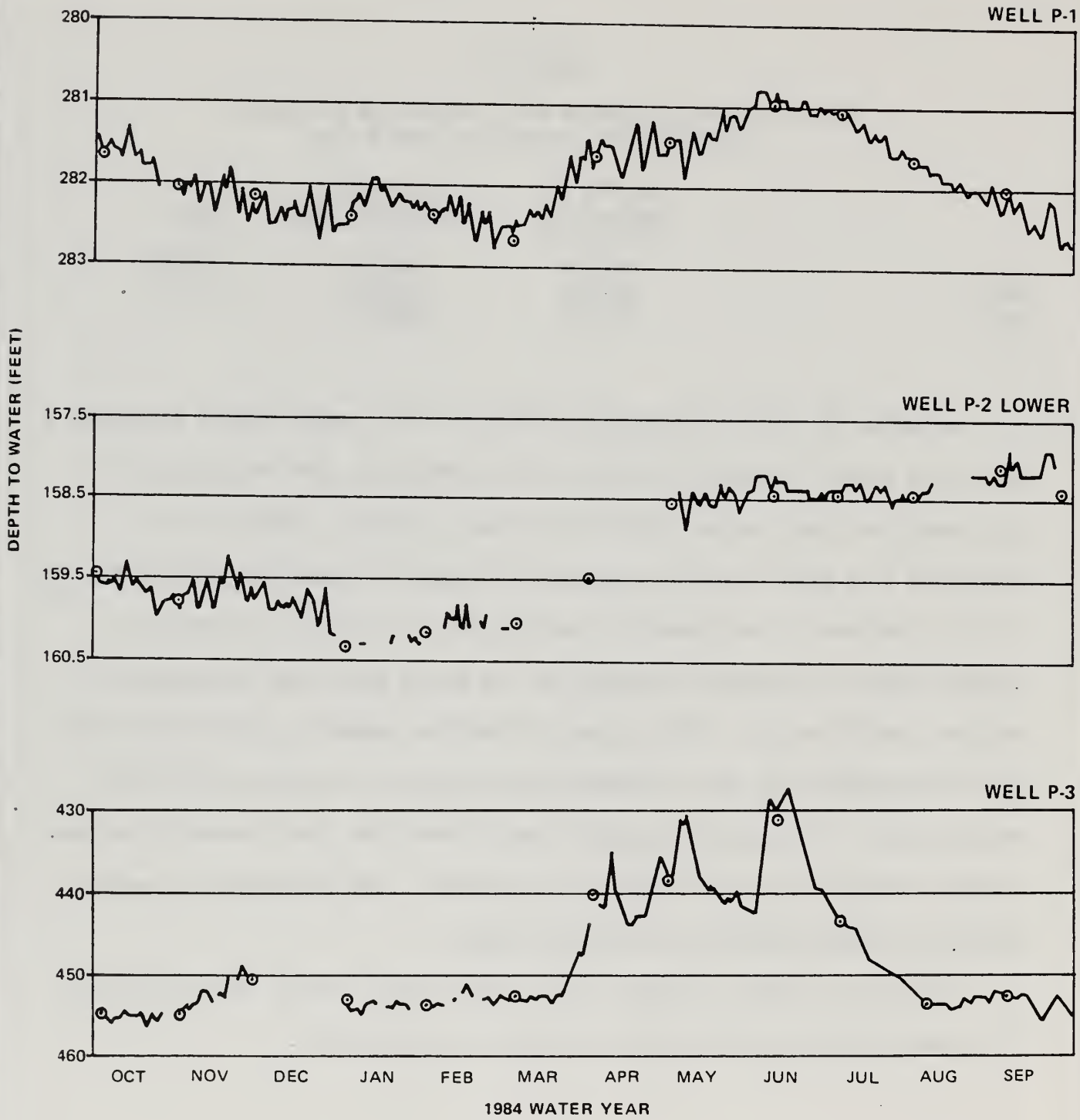
Well P-1

Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 5284.0 ft)

	Depth to Water (ft)	Ground Water Elevation (ft)	Date
Low	282.76	5001.24	2/27/84
High	280.78	5003.22	6/5/84
Mean	281.83	5002.17	

As shown on the P-1 hydrograph, Figure 6.4-12, water levels exhibited a declining trend from the beginning of the 1984 water year to February 27, 1984 when the lowest water level of the year occurred. Water levels recovered to a high in early June and then declined steadily through the end of the water year. The general fluctuation is believed to represent a general trend of recharge-discharge to the Birds Nest Zone in response to surface runoff events. This becomes evident by comparing the ground water level hydrograph with the discharge hydrograph for Evacuation Creek (see Figure 6.4-6). The spring snowmelt period (March to June) appeared to have a marked effect on water levels in the aquifer. The 1984 range of water levels was within previously observed ranges.

The annual extreme and mean daily static water levels recorded at well P-2 Lower during the 1984 water year are tabulated below.



LEGEND

⊙ INSTANTANEOUS MEASUREMENTS

1984 WATER LEVEL HYDROGRAPHS OF WELLS P-1, P-2 LOWER AND P-3

FIGURE 6.4-12

Well P-3

Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 5486.0 ft)

	Depth to Water (ft)	Ground Water Elevation (ft)	Date
Low	456.26	5029.74	10/21/83
High	426.93	5059.07	6/15/84
Mean	448.10	5037.90	

As shown on the P-3 hydrograph, Figure 6.4-12, only minor water level fluctuations occurred from the beginning of the water year through February 1984. Sharp increases in water level elevations occurred on April 10, May 8, and June 8-15, 1984. These increases correlate with high surface runoff occurring in the White River, with a lag time of approximately 17-20 days because of the delay in aquifer response to increased recharge. Peak discharges on the White River occurred on March 11, April 21, and May 19-27, 1984.

The annual range in water levels at P-3 during the 1984 water year was approximately 30 feet. Mean water level depth for the year was 448.1 feet, which is almost 2 feet above the long-term average of 450 feet.

G-Wells The continuous water level records collected from wells G-5 and G-11 in 1984 were generally unsatisfactory. During water quality sampling in December 1983, a submersible pump was accidently jammed in well G-5. Because drilling contractors were unavailable for several months, the pump was not removed until September 1984. Consequently, only 2 months of continuous water levels were available for G-5. The continuous water level record for G-11 was unacceptable due to repeated battery failure and float obstructions in the well casing. Consequently, the annual trends observed

at wells G-5 and G-11 were based on the static water level data only.

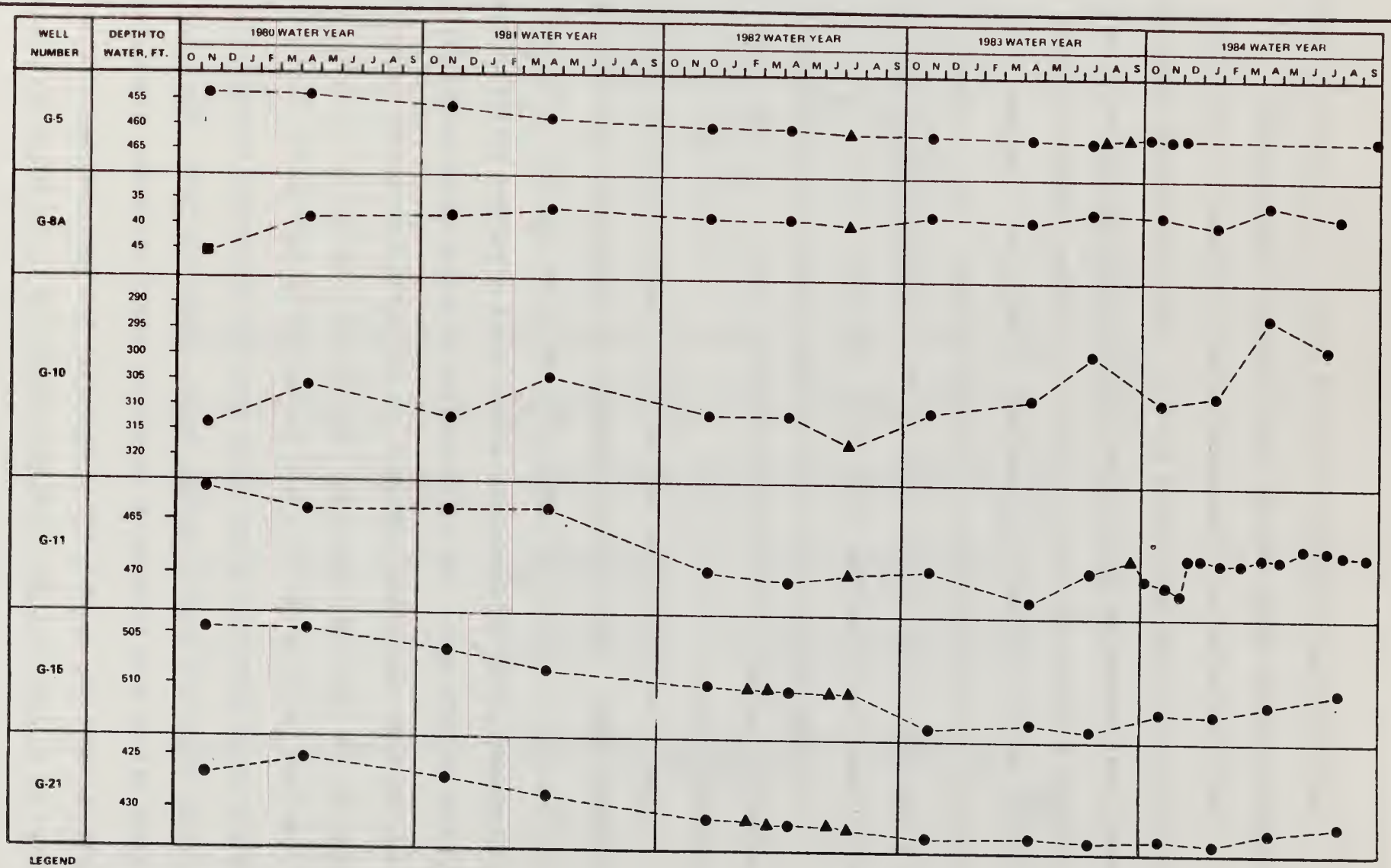
Well G-5 had four static water level measurements taken during the 1984 water year. As illustrated in the 1980-1984 hydrograph in Figure 6.4-13, the water level of G-5 has remained on a continual decline. This decline originated in late 1980 and early 1981 and was also evident in wells G-11, G-15 and G-21. A possible cause of this regional decline could be pumpage from the Birds Nest Zone in the area north of P-2 Lower (off tract). There is no evidence that WRSP activities are responsible for this general decline.

At Well G-11, static water level measurements were collected on a monthly basis (see Figure 6.4-13). During the 1984 water year, water levels in Well G-11 fluctuated a total of 3.35 feet and showed an overall rise in water level of 2.34 ft. The water level measurements for G-11 are presented below:

Well G-11

Static Water Level Measurements
(land surface elevation 5292.0 ft)

Date	Depth to Water (ft)	Ground Water Elevation (ft)
10/10/83	470.18	4821.82
11/8/83	470.70	4821.30
12/8/83	468.00	4824.00
1/3/84	468.28	4823.72
3/5/84	468.68	4823.32
5/7/84	468.31	4823.69
6/14/84	467.35	4824.65
7/16/84	467.44	4824.56
8/10/84	467.68	4824.32
9/12/84	467.84	4824.16



LEGEND

● SCHEDULED SEMI-ANNUAL WATER MEASUREMENT

▲ SUPPLEMENTAL WATER LEVEL MEASUREMENT

■ ANOMALOUS OR QUESTIONABLE MEASUREMENT

----- INTERPOLATED VALUES, MAY NOT REPRESENT ACTUAL CONDITIONS BETWEEN MEASUREMENTS

NOTE. WATER LEVELS FROM WELL G-14 ARE NOT AVAILABLE FOR THIS FIGURE. THE WELL WAS NON-FUNCTIONAL DUE TO SILTING FROM AUG. 1982 UNTIL DEC. 1983, WHEN WELL WAS CLEANED.

STATIC WATER LEVELS IN G-WELLS
WATER YEARS 1980 – 1984

FIGURE 6.4-13

As illustrated on Figure 6.4-13 the water level at G-11 has recovered slightly from the large decline that occurred in 1982 and 1983.

Quarterly water level measurements were also made at wells G-8A, G-10, G-14, G-15, and G-21 (see Figure 6.4-13). These wells exhibited similar water level recoveries during 1984. Most notable was well G-10, which exhibited a 15.45 foot rise in water level between January and April 1984.

All wells, with the exception of G-5, exhibited a recovery from a long-term decline which has occurred for several years. It is probable that the G-5 area may be slow in responding to the discharge-recharge conditions which seem to be occurring in the Birds Nest Zone.

B. Water Quality Water quality samples were collected once for laboratory analysis at each of the following wells: P-2 Lower, G-5, G-8A, G-11 and G-14.

P-Wells Well P-2 Lower had one water quality sample collected in September 1984. These data are compared to the baseline data from this well in Table 6.4-11. The water quality of the Birds Nest Zone at this well was predominantly sodium-bicarbonate with a total dissolved solids (TDS) concentration of 1574 mg/l. The concentration of sodium exhibited an increase over baseline conditions (524 mg/l vs. 460 mg/l) and specific conductance equalled the baseline conditions (524 mg/l vs. 460 mg/l) and specific conductance equalled the baseline maximum (2370 micromhos). Other parameters which exhibited values above baseline conditions included oil and grease, dissolved organic carbon, boron, copper and iron. The boron and copper values were believed to be within normal variation, since copper was detected near the lower limit of detection and boron has been commonly detected in concentrations exceeding 1000 ug/l in the Birds Nest Zone and

TABLE 6.4-11

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL P-2 LOWER

	No. of Samples	1975 - 1977 Minimum	Maximum	Mean	Standard Deviation	1984 Value	Exceedances of Baseline
Water Temperature (°C)	11	14.0	16.5	15.36	0.87	13.0	
pH, field (units)	13	7.8	10.3	8.75	0.70	9.3	
Color (pcu)	11	§1	40	--	--	15	
Specific Conductance, field (umhos/cm)	12	1800	2370	2013.3	163.2	2370	*
Total Dissolved Solids, Residue @ 180°C (mg/l)	13	1210	1630	1370.0	112.1	1520	
Total Dissolved Solids, calculated sum (mg/l)	13	1240	1590	1406.2	98.6	1570	
Hardness, total (mg/l as $CaCO_3$)	13	80	210	138.5	39.5	151	
Hardness, noncarbonate (mg/l as $CaCO_3$)	13	0	0	0	0	0	
Alkalinity (mg/l as $CaCO_3$)	13	368	892	548.4	155.8	722	
Chemical Oxygen Demand (mg/l)	10	8.0	100.0	68.70	34.02	51	
Oil and Grease, total (mg/l)	9	§1	4	--	--	18	*
Dissolved Organic Carbon (mg/l)	1	2.9	2.9	2.9	--	5.0	*
Phenols (ug/l)	2	2	2	2.0	0.0	§2	
Ammonia dissolved (mg/l as N)	13	0.430	3.900	0.9577	0.9707	0.77	
Ammonia + Org. nitrogen, total (mg/l as N)	13	0.51	5.0	1.26	1.25	0.90	
Nitrite, dissolved (mg/l as N)	12	§0.01	0.040	--	--	§0.02	
Nitrite plus Nitrate, dissolved (mg/l as N)	13	0.0[illegible]	§0.10	--	--	§0.02	
Orthophosphorus, dissolved (mg/l as P)	13	0.0[illegible]	0.090	0.0362	0.0260	§0.01	
Phosphorus, total (mg/l as P)	13	§0.0[illegible]	0.160	--	--	0.06	
Silica, dissolved (mg/l as SiO_2)	13	3.3	19	14.20	4.91	17	
Calcium, dissolved (mg/l)	13	5.1	30	15.28	7.87	21	
Magnesium, dissolved (mg/l)	13	16	32	23.9	4.9	24	
Sodium, dissolved (mg/l)	13	410	460	436.2	16.6	524	*
Sodium Adsorption Ratio	13	13	20	16.6	2.4	19	
Percent Sodium	13	83	92	87.4	3.0	88	
Potassium, dissolved (mg/l)	13	1.4	3.3	1.95	0.56	1.5	
Sulfate, dissolved (mg/l)	13	310	730	493.1	117.4	470	
Chloride, dissolved (mg/l)	13	30	82	47.0	18.6	78	
Fluoride, dissolved (mg/l)	13	0.90	1.3	1.12	0.14	1.3	
Boron, dissolved (ug/l)	13	360	1200	725.4	238.3	1360	*
Aluminum, dissolved (ug/l)	11	§10	§100	--	--	17	
Arsenic, dissolved (ug/l)	13	1	19	6.2	5.3	16	
Barium, dissolved (ug/l)	11	20	§100	--	--	15	
Beryllium, dissolved (ug/l)	10	§10	20	--	--	§5	
Cadmium, dissolved (ug/l)	11	§2	§2	--	--	§0.1	
Chromium, dissolved (ug/l)	11	§20	§25	--	--	§1	
Copper, dissolved (ug/l)	13	§2	2	--	--	3	*
Iron, dissolved (ug/l)	13	§10	320	--	--	420	*
Lead, dissolved (ug/l)	11	§2	§2	--	--	1	
Manganese, dissolved (ug/l)	11	§10	250	--	--	250	*
Mercury, dissolved (ug/l)	13	§0.1	0.5	--	--	0.3	
Molybdenum, dissolved (ug/l)	11	§1	140	--	--	31	
Nickel, dissolved (ug/l)	10	§2	16	--	--	§1	
Selenium, dissolved (ug/l)	13	§1	§1	--	--	§1	
Silver, dissolved (ug/l)	10	§2	§2	--	--	§0.2	
Strontium, dissolved (ug/l)	13	950	3300	2342.3	738.8	2600	
Vanadium, dissolved (ug/l)	11	§0.1	5.7	--	--	2	
Zinc, dissolved (ug/l)	13	§20	80	--	--	§5	

alluvial wells (VTN 1976 and 1977). The high iron levels were believed to be due to contamination from the iron well casing (VTN 1984e). Oil and grease and dissolved organic carbon values were above what would be considered as normal variation for ground water in this zone. The increases could possibly be the result of sample contamination, laboratory error, or other activities not related to WRSP.

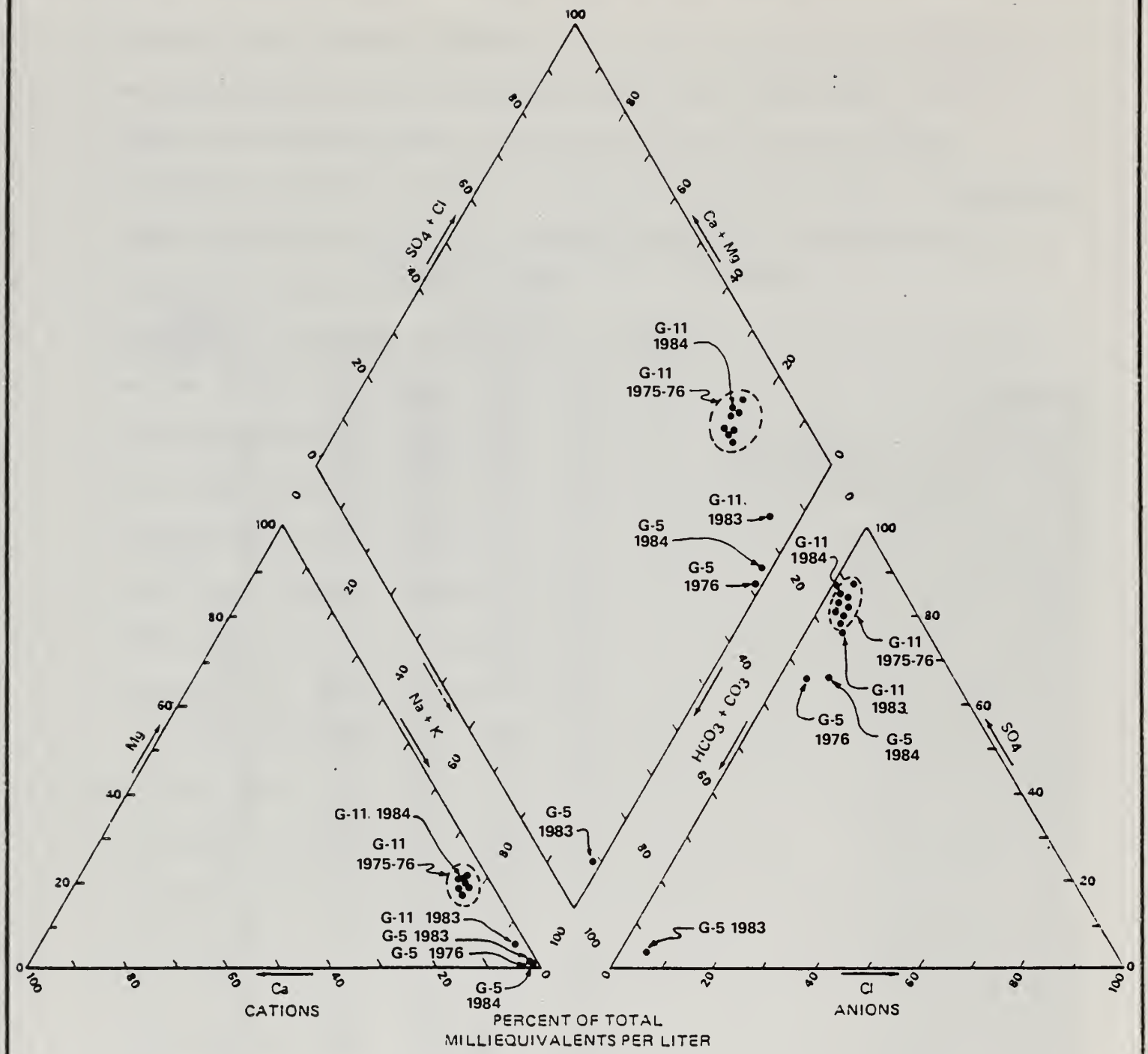
G-Wells The water quality data collected at well G-5 during baseline and for 1984 are presented in table 6.4-12. A major shift in water quality character during 1984 was detected at well G-5. This well, which typically was a sodium-sulfate type water during baseline, shifted to a sodium-bicarbonate type water during 1983, and in 1984 the water quality indicated a shift back towards a sodium-sulfate type water (see Figure 6.4-14). These shifts in the water quality of G-5 may be attributed to the decline in the Birds Nest Zone which has been observed in the northern part of tract Ua.

Holmes and Kimball (1983) have suggested that water recharging the Birds Nest Zone from the White River contributed to the water quality change from sodium-sulfate to a sodium-bicarbonate type water. Thus, the decline in the Birds Nest Zone water levels during 1982 and 1983 could have induced recharge from the White River, which, subsequently, affected water quality at well G-5. It has been previously noted (VTN 1976 and 1977) that there is a distinct difference in the water quality in the Birds Nest Zone in an area near the border between tracts Ua and Ub. Well G-5 lies on this transition zone and would probably be more readily influenced than other wells being monitored. This belief is also supported by the radical shifts in water quality types seen at this well during the baseline period when it shifted from a sodium-bicarbonate-sulfate to a sodium-bicarbonate (1975) and then to a sodium-sulfate type water (1976).

TABLE 6.4-12

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL G-5

	No. of Samples	1974 - 1977 Minimum	Maximum	Mean	Standard Deviation	1984 Value	Exceedances of Baseline
Water Temperature (°C)	7	16.5	17.5	16.93	0.45	--	
pH, field (units)	7	8.0	10.2	8.80	0.77	9.0	
Color (pcu)	6	15	200	69.7	70.8	5	
Specific Conductance, field (umhos/cm)	6	2400	4700	3586.7	980.7	3510	
Total Dissolved Solids, Residue @ 180°C (mg/l)	6	1700	3150	2391.7	623.1	2370	
Total Dissolved Solids, calculated sum (mg/l)	7	1820	3400	2590.0	635.0	2370	
Hardness, total (mg/l as $CaCO_3$)	7	15	200	98.4	70.1	36	
Hardness, noncarbonate (mg/l as $CaCO_3$)	7	0	0	0.0	0.0	0	
Alkalinity (mg/l as $CaCO_3$)	7	400	1290	950.4	309.9	645	
Chemical Oxygen Demand (mg/l)	7	180	370	254.3	69.5	80	
Oil and Grease, total (mg/l)	7	§1	8	--	--	18	*
Dissolved Organic Carbon (mg/l)	1	5.8	5.8	5.80	--	17	*
Phenols (ug/l)	1	3	3	3.0	--	§2	
Ammonia dissolved (mg/l as N)	7	0.79	2.90	1.827	0.848	1.0	
Ammonia + Org. nitrogen, total (mg/l as N)	7	1.2	3.0	2.36	0.63	1.4	
Nitrite, dissolved (mg/l as N)	7	§0.01	0.02	--	--	§0.01	
Nitrite plus Nitrate, dissolve (mg/l as N)	7	0.02	§0.10	--	--	§0.02	
Orthophosphorus, dissolved (mg as P)	7	0.01	0.32	0.093	0.111	§0.01	
Phosphorus, total (mg/l as P)	7	0.05	0.90	0.207	0.308	0.12	
Silica, dissolved (mg/l as SiC	7	15	27	21.3	4.8	2.8	
Calcium, dissolved (mg/l)	7	1.8	75	17.50	25.99	6.0	
Magnesium, dissolved (mg/l)	7	2.2	28	12.57	10.15	5.0	
Sodium, dissolved (mg/l)	7	580	1100	874.3	200.2	835	
Sodium Adsorption Ratio	7	20	69	48.0	17.2	61	
Percent Sodium	7	88	99	95.3	3.8	98	
Potassium, dissolved (mg/l)	7	1.8	8.1	3.57	2.17	2.8	
Sulfate, dissolved (mg/l)	7	91	1200	557.3	359.8	995	
Chloride, dissolved (mg/l)	7	50	580	367.1	179.6	127	
Fluoride, dissolved (mg/l)	7	1.2	2.8	1.93	0.62	1.2	
Boron, dissolved (ug/l)	7	1800	8200	5671.4	2711.5	2040	
Aluminum, dissolved (ug/l)	7	10	§100	--	--	17	
Arsenic, dissolved (ug/l)	7	1	210	72.1	82.8	4	
Barium, dissolved (ug/l)	7	§100	600	--	--	70	
Beryllium, dissolved (ug/l)	7	§10	§10	--	--	§5	
Cadmium, dissolved (ug/l)	7	§2	§2	--	--	§0.1	
Chromium, dissolved (ug/l)	7	§20	25	--	--	1	
Copper, dissolved (ug/l)	7	§2	12	--	--	2	
Iron, dissolved (ug/l)	7	60	120	88.6	23.4	70	
Lead, dissolved (ug/l)	7	§2	3	--	--	2	
Manganese, dissolved (ug/l)	7	20	60	35.7	19.9	20	
Mercury, dissolved (ug/l)	7	§0.1	§0.5	--	--	§0.1	
Molybdenum, dissolved (ug/l)	7	§1	3	--	--	77	*
Nickel, dissolved (ug/l)	7	§2	18	--	--	§1	
Selenium, dissolved (ug/l)	7	§1	§1	--	--	§1	
Silver, dissolved (ug/l)	7	§2	§2	--	--	§0.2	
Strontium, dissolved (ug/l)	7	860	4800	2594.3	1648.1	1110	
Vanadium, dissolved (ug/l)	7	0.5	28	9.87	10.49	§1	
Zinc, dissolved (ug/l)	7	§20	30	--	--	§5	



TRILINEAR DIAGRAM SHOWING WATER QUALITY TRENDS AT WELLS G-5 AND G-11

FIGURE 6.4-14

The water quality comparison between baseline and 1984, indicates three parameters which exceeded previously recorded baseline conditions. They include oil and grease, dissolved organic carbon and molybdenum. These relatively minor exceedances are believed to be natural variation and not related to project activities.

Well G-11 was sampled in December 1983 and September 1984 (Table 6.4-13). The water quality characteristics during the two periods were extremely similar, both being a sodium-sulfate type water. The two samples varied only slightly in TDS (4730 mg/l versus 4760 mg/l). The only considerable difference between the two sample periods was the higher manganese value of 640 ug/l in September 1984 as compared to 20 ug/l in December 1983. Other minor differences are attributed to differences in lower limit of detection between the USGS Laboratory and Bookcliffs Commercial Laboratory.

Comparison of the water quality data collected for G-11 with the baseline record, indicates that all major parameters are within previously observed ranges with the exceptions of manganese and strontium. The high value of manganese (VTN 1984e), is attributed to contamination of the sample from the iron-manganese well casing. The strontium concentration was 13,700 ug/l, compared to a baseline high of 13,000 ug/l. High strontium values in the Birds Nest Zone are common and this value is believed to be within natural variation of the aquifer. Figure 6.4-14 presents a trilinear diagram comparing baseline samples and the 1984 data. This diagram shows that little change in water quality type (sodium-sulfate) has occurred.

Laboratory water quality samples were also collected at wells, G-8A and G-14 for purposes of re-establishing baseline conditions. Well G-8A,

TABLE 6.4-13

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL G-11

	1974 - 1977					1984			
	No. of Samples	Minimum	Maximum	Mean	Standard Deviation	No. of Samples	Minimum	Maximum	Exceedances of Baseline
Water Temperature (°C)	6	15.5	19.0	17.08	1.39	2	18.0	18.0	
pH field (units)	6	7.5	8.4	7.92	0.39	2	7.4	7.4	
Color (pcu)	4	3	360	144.5	169.6	2	5	80	
Specific Conductance, field (umhos/cm)	6	5600	6100	5956.7	188.9	2	5900	5900	
Total Dissolved Solids, Residue @ 180°C (mg/l)	6	4310	4970	4735.0	226.0	2	4730	4760	
Total Dissolved Solids, calculated sum (mg/l)	6	4570	5090	4806.7	221.5	2	4590	4870	
Hardness, total (mg/l as $CaCO_3$)	6	750	920	836.7	61.2	2	808	882	
Hardness, noncarbonate (mg/l as $CaCO_3$)	6	140	520	311.7	146.8	2	207	422	
Alkalinity (mg/l as $CaCO_3$)	6	365	610	526.5	97.0	2	460	601	
Chemical Oxygen Demand (mg/l)	6	19.0	310.0	139.83	94.70	2	73	190	
Oil and Grease, total (mg/l)	6	1	12	6.3	4.8	2	3	7	
Dissolved Organic Carbon (mg/l)	1	11	11	11.0	--	2	11	11	
Phenols (ug/l)	1	3	3	3.0	--	2	§2	2	
Ammonia dissolved (mg/l as N)	6	1.90	2.90	2.383	0.355	2	2.2	2.8	
Ammonia + Org. nitrogen, total (mg/l as N)	6	2.7	4.4	3.18	0.64	2	2.9	3.0	
Nitrite, dissolved (mg/l as N)	6	§0.010	0.010	--	--	2	§0.01	§0.01	
Nitrite plus Nitrate, dissolved (mg/l as N)	6	0.01	0.10	0.06	0.05	2	§0.02	§0.10	
Orthophosphorus, dissolved (mg/l as P)	6	§0.010	0.400	--	--	2	§0.01	0.10	
Phosphorus, total (mg/l as P)	6	§0.010	0.420	--	--	2	0.04	0.05	
Silica, dissolved (mg/l as SiO_2)	6	24	27	25.2	1.2	2	17	26	
Calcium, dissolved (mg/l)	6	48	69	63.0	7.6	2	60	68	
Magnesium, dissolved (mg/l)	6	140	180	161.67	14.72	2	160	173	
Sodium, dissolved (mg/l)	6	1200	1300	1233.3	51.6	2	1200	1260	
Sodium Adsorption Ratio	6	18	19	18.7	0.5	2	18	18	
Percent Sodium	6	76	78	76.5	0.8	2	76	76	
Potassium, dissolved (mg/l)	6	3.4	5.9	4.42	0.88	2	3.5	4.7	
Sulfate, dissolved (mg/l)	6	2600	3100	2800.0	200.0	2	2700	2960	
Chloride, dissolved (mg/l)	6	75	140	95.3	25.3	2	78	107	
Fluoride, dissolved (mg/l)	6	0.9	1.2	1.05	0.12	2	1.0	1.1	
Boron, dissolved (ug/l)	6	3000	4000	3666.7	344.5	2	3570	3700	
Aluminum, dissolved (ug/l)	6	10	200	90.0	66.9	2	§10	17	
Arsenic, dissolved (ug/l)	6	§1	3	--	--	2	§1	1	
Barium, dissolved (ug/l)	6	§20	§100	--	--	2	3	§100	
Beryllium, dissolved (ug/l)	6	§10	10	--	--	2	§5	§10	
Cadmium, dissolved (ug/l)	6	§2	§2	--	--	2	§0.1	§1.0	
Chromium, dissolved (ug/l)	6	§20	§85	--	--	2	§1	10	
Copper, dissolved (ug/l)	6	§2	§20	--	--	2	§1	4	
Iron, dissolved (ug/l)	6	20	320	150.0	111.0	2	80	140	
Lead, dissolved (ug/l)	6	§2	§85	--	--	2	§1	3	
Manganese, dissolved (ug/l)	6	§10	60	--	--	2	20	640	*
Mercury, dissolved (ug/l)	5	§0.1	§0.5	--	--	2	0.2	0.4	
Molybdenum, dissolved (ug/l)	6	§1	23	--	--	2	§1	4	
Nickel, dissolved (ug/l)	6	§2	§84	--	--	2	§1	§1	
Selenium, dissolved (ug/l)	6	§1	§1	--	--	2	§1	§1	
Silver, dissolved (ug/l)	6	§2	§2	--	--	2	0.3	1.0	
Strontium, dissolved (ug/l)	6	9700	13000	11616.7	1296.8	2	11000	13700	*
Vanadium, dissolved (ug/l)	6	§0.1	3.9	--	--	2	§1	1	
Zinc, dissolved (ug/l)	6	§20	150	--	--	2	7	30	

located in Evacuation Creek drainage, revealed a sodium-sulfate type water, which also was characteristic of data collected during the baseline period (see Table 6.4-14). Parameters which exceeded previously recorded baseline maximum values included color, hardness, alkalinity, dissolved organic carbon, phenols, silica, calcium, magnesium, copper, iron, manganese, strontium and zinc. Calcium and magnesium exhibited slight increases (10 mg/l) as did hardness and alkalinity. Dissolved organic carbon and phenols were detected slightly above baseline conditions, however, the baseline data consisted of only 2 values and the current numbers are probably within normal variation. The slight increases in color and silica also are believed to be within natural variation. Of the trace materials analyzed, only manganese and strontium exhibited marked increases. The high manganese value is probably associated with contamination from the well casing (VTN 1984e). Strontium has characteristically been detected in high concentrations and this value is believed to be representative of natural conditions.

Well G-14 is also located in the Evacuation Creek drainage. During the baseline period this water was sodium-sulfate type water and remained so during 1984 (Table 6.4-15). The following parameters exhibited values that vary outside of ranges established during the baseline period, and include pH, alkalinity, orthophosphorus, phosphorus, silica, fluoride, boron, mercury and zinc. Although alkalinity, fluoride, boron and mercury were slightly above baseline conditions recorded to date, they are believed to be representative of existing conditions. Field pH which was slightly below baseline conditions to date. Baseline data collected to date incoporates variabilities within the last 10 years. Values ranging outside current

TABLE 6.4-14

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL G-8A

		1974 - 1977				1984	
	No. of Samples	Minimum	Maximum	Mean	Standard Deviation	Value	Exceedances of Baseline
Water Temperature (^{o}C)	7	10.5	13.0	11.79	0.91	13.0	
pH field (units)	6	7.2	8.0	7.62	0.30	7.3	
Color (pcu)	7	3	65	15.0	22.3	70	*
Specific Conductance, field (umhos/cm)	7	4500	5000	4717.1	198.9	4060	
Total Dissolved Solids, Residue @ 180°C (mg/l)	7	3760	4320	4050.0	214.4	3570	
Total Dissolved Solids, calculated sum (mg/l)	7	3500	4030	3778.6	208.3	3560	
Hardness, total (mg/l as $CaCO_3$)	7	1100	1300	1214.3	69.0	1400	*
Hardness, noncarbonate (mg/l as $CaCO_3$)	7	600	820	737.1	73.6	720	
Alkalinity (mg/l as $CaCO_3$)	7	456	528	496.9	27.6	663	*
Chemical Oxygen Demand (mg/l)	7	24.0	79.0	39.71	18.77	43	
Oil and Grease, total (mg/l)	7	§1	3	--	--	§1	
Dissolved Organic Carbon (mg/l)	2	11	13	12.0	1.4	15	
Phenols (ug/l)	2	§1	1	--	--	3	
Ammonia dissolved (mg/l as N)	7	0.06	0.18	0.100	0.046	0.14	
Ammonia + Org. nitrogen, total (mg/l as N)	7	0.14	1.3	0.63	0.39	0.60	
Nitrite, dissolved (mg/l as N)	7	0.009	0.030	0.0127	0.0076	§0.01	
Nitrite plus Nitrate, dissolved (mg/l as N)	7	0.02	0.16	0.06	0.05	0.14	
Orthophosphorus, dissolved (mg/l as P)	7	§0.01	0.04	--	--	0.02	
Phosphorus, total (mg/l as P)	7	§0.01	0.65	--	--	0.03	
Silica, dissolved (mg/l as SiO_2)	7	13	16	14.3	1.1	18	*
Calcium, dissolved (mg/l)	7	170	210	194.3	12.7	220	*
Magnesium, dissolved (mg/l)	7	170	190	180.0	8.2	200	*
Sodium, dissolved (mg/l)	7	720	850	785.7	53.2	650	
Sodium Adsorption Ratio	7	9.3	11.0	9.80	0.61	7.6	
Percent Sodium	7	57	60	58.0	1.0	51	
Potassium, dissolved (mg/l)	7	4.5	8.6	7.10	1.46	5.1	
Sulfate, dissolved (mg/l)	7	2000	2400	2228.6	149.6	2000	
Chloride, dissolved (mg/l)	7	52	59	56.0	2.4	53	
Fluoride, dissolved (mg/l)	7	0.9	1.4	1.20	0.15	1.3	
Boron, dissolved (ug/l)	7	1900	2700	2200.0	264.6	2000	
Aluminum, dissolved (ug/l)	7	§10	§100	--	--	50	
Arsenic, dissolved (ug/l)	7	3	24	14.1	8.6	5	
Barium, dissolved (ug/l)	7	§100	§100	--	--	§100	
Beryllium, dissolved (ug/l)	7	§10	20	--	--	§10	
Cadmium, dissolved (ug/l)	7	§2	§2	--	--	2	
Chromium, dissolved (ug/l)	7	§20	§65	--	--	§10	
Copper, dissolved (ug/l)	7	§2	6	--	--	7	*
Iron, dissolved (ug/l)	7	310	4600	1994.3	1821.9	5400	*
Lead, dissolved (ug/l)	7	§2	4	--	--	2	
Manganese, dissolved (ug/l)	7	110	230	158.6	44.9	1100	*
Mercury, dissolved (ug/l)	7	§0.1	§0.5	--	--	§0.1	
Molybdenum, dissolved (ug/l)	7	39	64	50.6	10.0	53	
Nickel, dissolved (ug/l)	7	§2	19	--	--	9	
Selenium, dissolved (ug/l)	7	§1	1	--	--	§1	
Silver, dissolved (ug/l)	7	§2	§2	--	--	§1	
Strontium, dissolved (ug/l)	7	4200	5700	5228.6	610.2	6700	*
Vanadium, dissolved (ug/l)	7	§0.1	3.1	--	--	2.6	
Zinc, dissolved (ug/l)	7	20	90	48.6	25.4	120	*

TABLE 6.4-15

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL G-14

		1974 - 1977				1984	
	No. of Samples	Minimum	Maximum	Mean	Standard Deviation	Value	Exceedances of Baseline
Water Temperature (°C)	5	10.0	13.5	11.00	1.41	13.0	
pH field (units)	5	7.7	8.4	8.06	0.33	7.6	*
Color (pcu)	5	5	30	12.2	10.1	30	*
Specific Conductance, field (umhos/cm)	5	3200	3600	3370.0	156.5	3300	
Total Dissolved Solids, Residue @ 180°C (mg/l)	5	2370	2820	2576.0	181.5	2390	
Total Dissolved Solids, calculated sum (mg/l)	5	2280	2760	2544.0	192.6	2400	
Hardness, total (mg/l as $CaCO_3$)	5	500	620	552.0	54.5	500	
Hardness, noncarbonate (mg/l as $CaCO_3$)	5	0	58	13.2	25.3	0	
Alkalinity (mg/l as $CaCO_3$)	5	492	633	580.6	56.7	676	*
Chemical Oxygen Demand (mg/l)	5	45	140	103.6	37.5	110	
Oil and Grease, total (mg/l)	5	§1	6	--	--	4	
Dissolved Organic Carbon (mg/l)	0	--	--	--	--	24	
Phenols (ug/l)	1	3	3	3.0	0.0	2	
Ammonia dissolved (mg/l as N)	5	1.10	1.50	1.300	0.158	1.5	
Ammonia + Org. nitrogen, total (mg/l as N)	5	1.4	3.1	1.82	0.72	1.8	
Nitrite, dissolved (mg/l as N)	5	§0.01	0.01	--	--	§0.01	
Nitrite plus Nitrate, dissolved (mg/l as N)	5	0.01	§0.10	--	--	§0.10	
Orthophosphorus, dissolved (mg/l as P)	5	0.01	0.05	0.030	0.016	0.32	*
Phosphorus, total (mg/l as P)	5	0.01	0.08	0.032	0.028	0.11	*
Silica, dissolved (mg/l as SiO_2)	5	27	28	27.2	0.45	34	*
Calcium, dissolved (mg/l)	5	40	60	46.8	8.9	35	
Magnesium, dissolved (mg/l)	5	94	110	102.0	7.6	97	
Sodium, dissolved (mg/l)	5	580	680	640.0	42.43	620	
Sodium Adsorption Ratio	5	11	12	11.8	0.45	12	
Percent Sodium	5	71	73	72.2	0.8	73	
Potassium, dissolved (mg/l)	5	2.3	8.0	3.96	2.32	2.3	
Sulfate, dissolved (mg/l)	5	1100	1400	1220.0	130.4	1100	
Chloride, dissolved (mg/l)	5	74	100	87.4	9.3	89	
Fluoride, dissolved (mg/l)	5	0.6	0.8	0.74	0.09	0.9	*
Boron, dissolved (ug/l)	5	40	3600	1948.0	1462.7	3700	*
Aluminum, dissolved (ug/l)	5	§10	§100	--	--	10	
Arsenic, dissolved (ug/l)	5	5	48	22.0	16.2	4	
Barium, dissolved (ug/l)	5	13	§100	--	--	§100	
Beryllium, dissolved (ug/l)	5	§10	20	--	--	§10	
Cadmium, dissolved (ug/l)	5	§2	§2	--	--	§1	
Chromium, dissolved (ug/l)	5	§20	§45	--	--	§10	
Copper, dissolved (ug/l)	5	§2	§2	--	--	§1	
Iron, dissolved (ug/l)	5	60	180	106.0	49.8	70	
Lead, dissolved (ug/l)	5	§2	2	--	--	§1	
Manganese, dissolved (ug/l)	5	§10	30	--	--	30	
Mercury, dissolved (ug/l)	4	§0.1	§0.5	--	--	0.5	*
Molybdenum, dissolved (ug/l)	5	§1	5	--	--	§1	
Nickel, dissolved (ug/l)	5	§2	8	--	--	§1	
Selenium, dissolved (ug/l)	5	§1	2	--	--	§1	
Silver, dissolved (ug/l)	5	§2	§2	--	--	§1	
Strontium, dissolved (ug/l)	5	9400	12000	10880.0	933.8	12000	
Vanadium, dissolved (ug/l)	5	0.2	3.9	1.94	1.73	1.8	
Zinc, dissolved (ug/l)	5	20	30	28.0	4.5	70	*

baseline data should not necessarily be considered as unusual or abnormal variations. Orthophosphorus, phosphorus, silica, and zinc however, were above what may be considered natural variation. No explanation is evident but possible causes include laboratory error, sample contamination, an other activity not related to the WRSP.

6.4.3.2 Uinta Formation The Uinta Formation monitored on the tracts does not appear to constitute a pervasive water-bearing zone. Rather, ground water appears to occur in localized areas where recharge, lithology (rock porosity) and structure combine to create localized water-bearing zones. Other than the retention dam wells, which are discussed in section 6.4.3.4, well P-2 Upper is the only well completed in a water-bearing zone of the Uinta Formation.

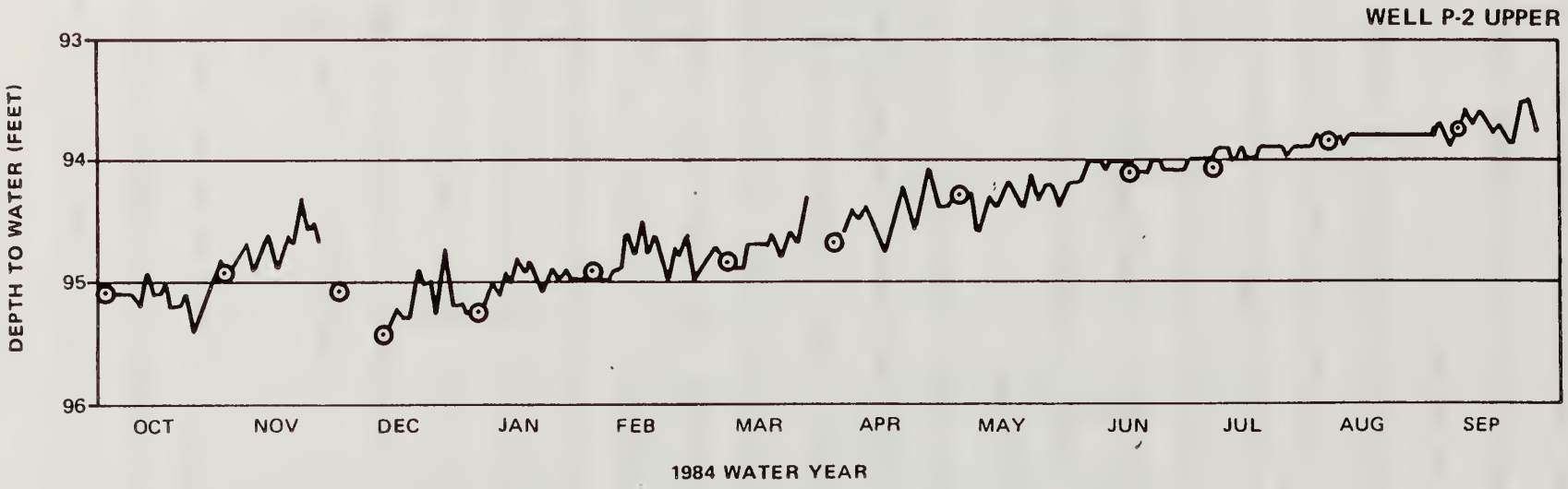
A. Water Levels Water level data collected in 1984 for P-2 Upper consisted of continuous water levels and monthly static water levels. The annual extremes and mean water level recorded at well P-2 Upper during the 1984 water year are tabulated below.

Well P-2 Upper

Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 4991.0 ft)

	Depth to Water (ft)	Ground Water Elevation (ft)	Date
High	93.47	4897.53	9/23/84
Low	95.44	4895.56	10/25/83
Mean	94.47	4896.53	

As shown on the P-2 Upper hydrograph on Figure 6.4-15, water level elevations generally rose from the beginning of the water year till the end



LEGEND

⊙ INSTANTANEOUS MEASUREMENT

1984 WATER LEVEL HYDROGRAPH
OF WELL P-2 UPPER

FIGURE 6.4-15

of November 1983. Water levels then declined to a low in December 1983 and then recovered throughout the rest of the water year except for minor dips in water level. The range in water levels at P-2 Upper during the 1984 water year was within the baseline range.

B. Water Quality One water quality sample was collected from P-2 Upper in September 1984 and the data are presented in Table 6.4-16. The laboratory water quality results indicated a sodium-sulfate type water with a TDS value of 3620 mg/l. Major ions which exhibited concentrations above previously observed baseline conditions included calcium, magnesium, sodium and sulfate. Correspondingly, specific conductance, TDS, and hardness were also slightly above baseline conditions.

Trace materials such as boron, iron, manganese, silver, strontium and vanadium were detected in 1984 above their respective baseline levels. Silver and vanadium were detected near their respective lower limits of detection and are considered natural variation. Iron and manganese were detected at levels substantially higher than what would be considered natural variation (280 ug/l vs. 970 ug/l and 60 ug/l vs. 220 ug/l, respectively). These values are believed to represent insufficient flushing of the well and contamination from the casing (VTN 1984e). Boron and strontium are two trace constituents which have always occurred in relatively high concentrations. The values of 430 ug/l for boron and 7000 ug/l for strontium are believed to be within the range of natural variation.

6.4.3.3 Southam Canyon Alluvium Ground water monitoring was conducted at four alluvial wells in Southam Canyon during 1984 including AG-7, G-2A, G-4A, and AG-6-1 Lower. However, as in most other years, all wells except

TABLE 6.4-16

BASELINE VERSUS 1984 WATER QUALITY DATA AT WELL P-2 UPPER

		1975 - 1977				1984	
	No. of Samples	Minimum	Maximum	Mean	Standard Deviation	Value	Exceedances of Baseline
Water Temperature (^{o}C)	11	13.5	17.5	15.45	1.04	14.0	
pH field (units)	11	7.8	8.5	8.08	0.22	8.2	
Color (pcu)	11	3	23	7.1	7.2	10	
Specific Conductance, field (umhos/cm)	11	3000	4480	3760.9	416.2	4670	*
Total Dissolved Solids, Residue @ 180°C (mg/l)	11	2630	3340	2911.8	236.2	3610	*
Total Dissolved Solids, calculated sum (mg/l)	11	2530	3400	2879.1	276.8	3760	*
Hardness, total (mg/l as $CaCO_3$)	11	230	440	305.5	60.9	491	*
Hardness, noncarbonate (mg/l as $CaCO_3$)	11	0	0	0.0	0.0	0	
Alkalinity (mg/l as $CaCO_3$)	11	474	554	522.3	26.8	546	
Chemical Oxygen Demand (mg/l)	10	4.0	79.0	18.90	22.03	26	
Oil and Grease, total (mg/l)	10	§1	39	--	--	1	
Dissolved Organic Carbon (mg/l)	1	1.7	1.7	1.7	--	5.0	*
Phenols (ug/l)	3	2	7	5.0	2.6	3	
Ammonia dissolved (mg/l as N)	11	1.60	2.30	1.946	0.225	2.2	
Ammonia + Org. nitrogen, total (mg/l as N)	11	1.5	3.4	2.25	0.61	2.3	
Nitrite, dissolved (mg/l as N)	11	§0.010	0.010	--	--	§0.02	
Nitrite plus Nitrate, dissolved (mg/l as N)	11	0.01	§0.10	--	--	§0.02	
Orthophosphorus, dissolved (mg/l as P)	11	§0.010	0.050	--	--	§0.01	
Phosphorus, total (mg/l as P)	11	§0.010	0.050	--	--	0.04	
Silica, dissolved (mg/l as SiO_2)	11	17	23	20.4	1.6	8.1	
Calcium, dissolved (mg/l)	11	19	44	29.82	6.37	45	*
Magnesium, dissolved (mg/l)	11	37	80	55.1	12.7	92	*
Sodium, dissolved (mg/l)	11	770	950	850.0	56.9	1030	*
Sodium Adsorption Ratio	11	20	23	21.6	1.1	20	
Percent Sodium	11	82	88	86.0	1.8	82	
Potassium, dissolved (mg/l)	11	1.5	11	2.94	2.71	2.5	
Sulfate, dissolved (mg/l)	11	1300	1900	1536.4	196.3	2180	*
Chloride, dissolved (mg/l)	11	47	82	60.4	9.3	68	
Fluoride, dissolved (mg/l)	11	0.40	0.80	0.50	0.13	0.3	
Boron, dissolved (ug/l)	11	180	340	306.4	44.8	430	*
Aluminum, dissolved (ug/l)	11	10	§100	--	--	49	
Arsenic, dissolved (ug/l)	11	§1	25	--	--	§1	
Barium, dissolved (ug/l)	11	20	§100	--	--	7	
Beryllium, dissolved (ug/l)	10	§10	20	--	--	§5	
Cadmium, dissolved (ug/l)	11	§2	§2	--	--	§0.1	
Chromium, dissolved (ug/l)	11	§20	§60	--	--	§1	
Copper, dissolved (ug/l)	11	§2	4	--	--	4	
Iron, dissolved (ug/l)	11	§10	280	--	--	970	*
Lead, dissolved (ug/l)	11	§2	2	--	--	§1	
Manganese, dissolved (ug/l)	11	20	60	36.4	13.6	220	*
Mercury, dissolved (ug/l)	11	§0.5	§0.5	--	--	§0.1	
Molybdenum, dissolved (ug/l)	11	11	74	30.9	19.7	8	
Nickel, dissolved (ug/l)	10	§2	4	--	--	§1	
Selenium, dissolved (ug/l)	11	§1	1	--	--	§1	
Silver, dissolved (ug/l)	10	§2	§2	--	--	0.2	
Strontium, dissolved (ug/l)	11	2700	6400	4681.8	917.4	7000	*
Vanadium, dissolved (ug/l)	11	§0.1	1.9	--	--	2	*
Zinc, dissolved (ug/l)	11	§20	70	--	--	9	

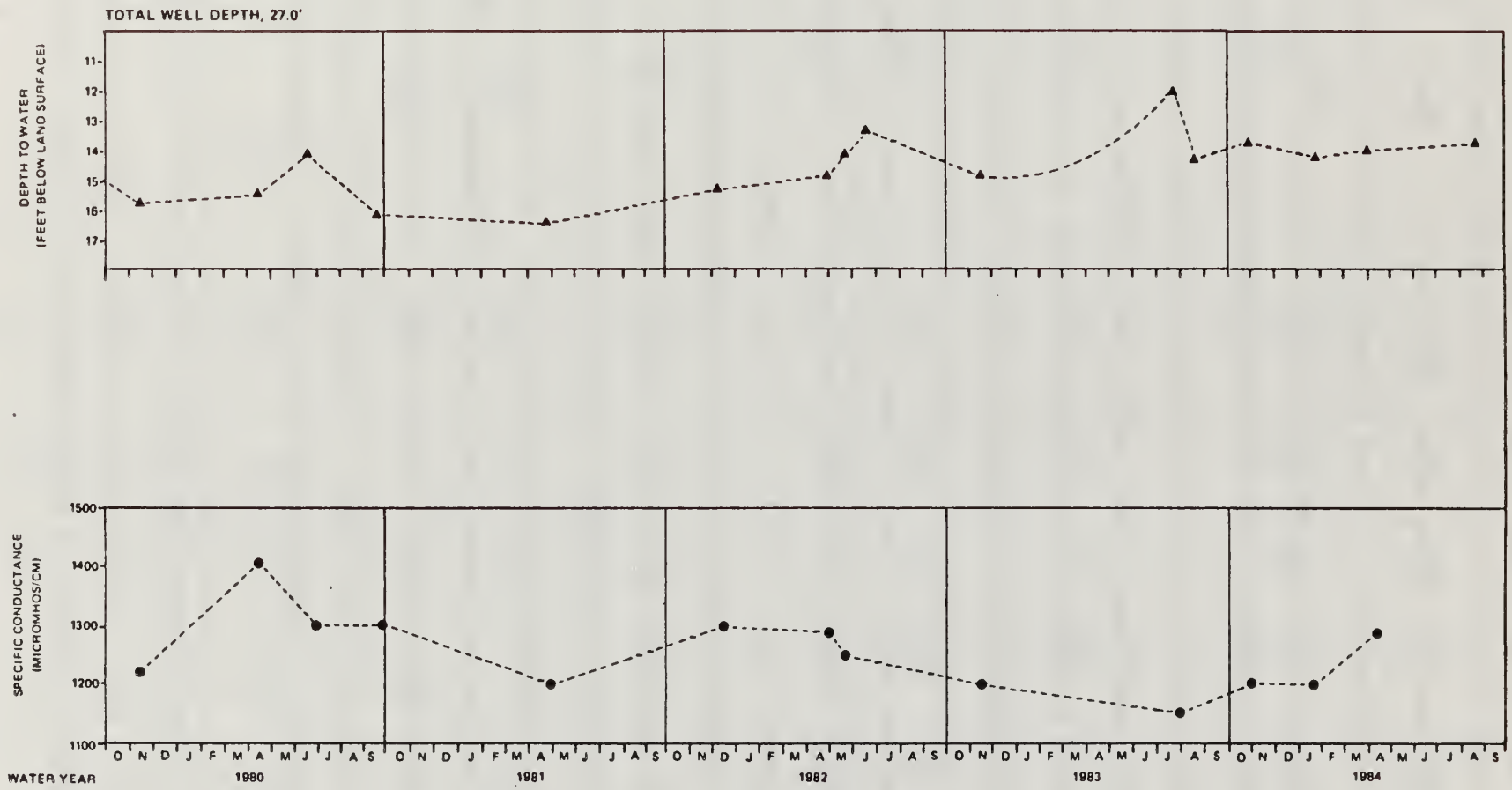
AG-6-1 Lower remained dry throughout the year. Therefore, the water level and water quality discussion is limited to Well AG-6-1.

A. Water Levels The static water levels collected at Well AG-6-1 Lower during 1984 are presented in Figure 6.4-16. Contrary to the 1983 water year and for several preceding years, water levels at this well did not fluctuate notably in 1984. Also no significant rise in water levels, coinciding with high water in the White River occurred in 1984.

B. Water Quality Field specific conductance readings were taken quarterly at well AG-6-1 during 1984. These values are also plotted on Figure 6.4-16. The specific conductance varied from 1200 to 1292 micromhos and were within the baseline range of values for this well.

6.4.3.4 Retention Dam Wells The retention dam monitoring well network, consisting of six multi-completion wells monitoring five distinct geologic zones and one alluvial well were installed in the Uinta Formation and Alluvium downstream of the Plant Site Wash Retention Dam in August and September of 1983. The drilling and completion of these wells was described in the report entitled "Drilling and Completion Report for Unita Formation and Alluvial Ground Water Monitoring Wells, Plant Site Wash Retention Dam" (VTN 1984b). Measurements of water levels were made initially following construction and continued into 1984 on a monthly basis. Water quality samples were collected only once in 1984 (August) due to a lack of water in most of the zones.

A. Water Levels Static water level measurements were collected on a monthly basis at all the retention dam wells. During 1984 wells UF-1-3, UF-2-1, UF-2-2, UF-2-3, UF-3-1, UF-4-1, UF-4-2, UF-5-1, UF-6-1, UF-6-2, and



LEGEND

▲ WATER LEVEL FIELD MEASUREMENT

● SPECIFIC CONDUCTANCE FIELD MEASUREMENT

----- INTERPOLATED VALUES, MAY NOT REPRESENT ACTUAL CONDITIONS BETWEEN MEASUREMENTS

STATIC WATER LEVELS AND SPECIFIC CONDUCTANCE IN WELL AG-6-1 LOWER, 1980 – 1984

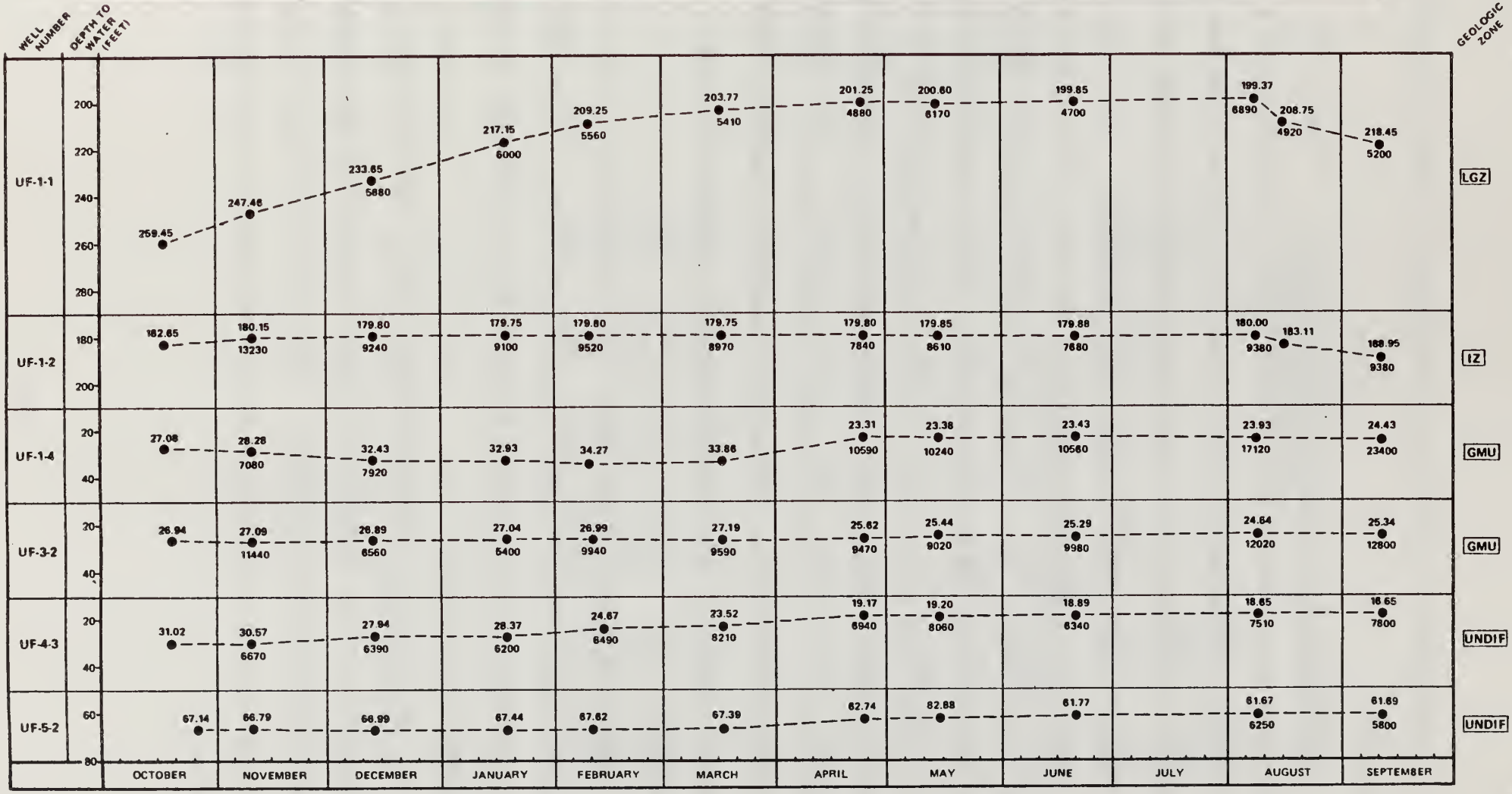
FIGURE 6.4-16

AG-10 were dry or nearly dry (water level did not exceed the top of the sump). The other monitoring wells, including UF-1-1, UF-1-2, UF-1-4, UF-3-2, UF-4-3 and UF-5-2 all had measurable quantities of ground water. The monthly water level measurements taken at these well are presented in Figure 6.4-17. Generally, all wells displayed similar characteristics with ground water levels initially rising until achieving a maximum elevation between April and June. Water levels then stabilized with only minor variations as a result of water quality sampling (bailing the well).

Undifferentiated Uinta Formation (UNDIF) The only wells in this formation which had measurable quantities of ground water were UF-4-3 and UF-5-2. Ground water in both of these wells achieved a maximum elevation in August 1984 of 5133.23 and 5138.86 feet, respectively. Both wells showed similar trends (Figure 6.4-17). The sudden increase in water level elevation between February and April is probably attributed to snowmelt runoff and consequent infiltration into the Uinta Formation.

Grey Marlstone Unit (GMU) Two wells, UF-1-4, UF-3-2, exhibited measurable ground water in this geologic zone. Well UF-3-2 achieved a maximum elevation of 5113.47 feet in August 1984 whereas UF-1-4 had a maximum elevation of 5107.48 in April 1984. Both of these wells showed similar trends with significant increases between March and April 1984. This attributed to snowmelt runoff and consequent infiltration of water into the strata.

Near Surface Porous Zone (NSPZ) Only one well, UF-1-3, had measurable water in this zone. However, water levels declined over the monitoring period and never achieved a height higher than the sump at the base of the



LEGENO

24.64 DEPTH TO WATER (FEET)

2345 SPECIFIC CONDUCTANCE (MICROMHOS/CM^2)

INTERPOLATEO WATER LEVELS, MAY NOT REPRESENT ACTUAL CONOITIONS BETWEEN MEASUREMENTS

1984 STATIC WATER LEVELS FOR THE RETENTION DAM WELLS

FIGURE 6.4-17

well. Consequently, the NSPZ can be considered dry with no measurable ground water.

Intermediate Zone (IZ) Only one well, UF-1-2, monitors the intermediate zone. Ground water levels ranged in elevation from a low of 4941.84 feet to a maximum of 4951.19 feet. The maximum elevation occurred in December 1983 and generally was stable over the monitoring period except for decreases associated with water quality sampling.

Lower Uinta Gradational Zone (LGZ) One well, UF-1-1, monitors ground water in this zone. The LGZ exhibited the most significant change in ground water levels during the monitoring period. Ground water elevations at UF-1-1 ranged from a low of 4871.34 feet during December 1983 to a maximum of 4931.42 feet in August 1984. The maximum elevation of 4931.42 feet is significant, as it is above the top of the monitoring zone suggesting semi-confined conditions. The decrease observed in September 1984 is probably a result of water quality sampling following the August measurement.

Plant Site Wash Alluvium Water levels in Well AG-10 never achieved an elevation higher than the sump at the base of the well. Consequently, the Plant Site Wash alluvium at this location can be considered dry with no measureable ground water.

B. Water Quality As with the water levels, the discussion of ground water quality for the retention dam wells is separated out by zones or units in which the wells were completed. Table 6.4-17 presents the laboratory water quality data collected for the retention dam wells during the 1984 water year.

TABLE 6.4-17

LABORATORY WATER QUALITY DATA
FOR THE RETENTION DAM WELLS

STATION NAME	DATE	TIME	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	PH, LAB (UNITS)	COLOR (PCU)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	SPECI-FIC CONDUC-TANCE LAB, UMHS@25	TOTAL DISS SOLIDS, RESIDUE @ 180 C (MG/L)	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)
UF-1-1	08/07/84	0755	14.0	9.6	9.3	35	5888	4940	4050	4187
UF-1-2	08/07/84	0915	14.0	8.1	7.7	190	9375	9100	8710	9042
UF-1-4	08/07/84	1110	16.0	6.7	7.5	20	17120	16900	16600	17366
UF-3-2	08/08/84	0830	13.0	7.9	6.6	25	12020	11700	11900	11647
UF-4-3	08/08/84	0945	13.5	6.9	6.3	25	7510	6890	6950	6791
UF-5-2	08/08/84	1130	16.0	6.9	7.0	17	6246	5460	5040	5120

STATION NAME	DATE	TIME	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCARB (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS (MG/L AS N)
UF-1-1	08/07/84	0755	223	30	193	130	4	39	19	1.7
UF-1-2	08/07/84	0915	1364	1274	90	95	2	28	32	3.0
UF-1-4	08/07/84	1110	5147	4649	498	65	1	23	41	1.1
UF-3-2	08/08/84	0830	3171	3137	34	100	1	20	11	5.2
UF-4-3	08/08/84	0945	2527	2424	103	55	1	14	<2	0.33
UF-5-2	08/08/84	1130	1349	1299	50	35	<1	13	<2	2.0

TABLE 6.4-17

LABORATORY WATER QUALITY DATA
FOR THE RETENTION DAM WELLS

(continued...)

STATION NAME	DATE	TIME	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	NITRITE DISS (MG/L AS N)	NITRITE PLUS NITRATE DISS (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO DISS., (MG/L AS P)	SILICA, DISS., (MG/L AS SIO2)	CAL-CIUM, DISS., (MG/L)	MAGNE-SIUM, DISS., (MG/L)
UF-1-1	08/07/84	0755	4.3	<0.01	<0.02	0.06	0.01	0.30	20	42
UF-1-2	08/07/84	0915	3.1	<0.01	<0.02	0.07	<0.01	0.40	337	127
UF-1-4	08/07/84	1110	1.7	<0.01	10	0.01	<0.01	7.6	469	966
UF-3-2	08/08/84	0830	6.6	<0.01	0.33	0.13	0.01	1.3	431	509
UF-4-3	08/08/84	0945	0.60	<0.01	<0.02	0.01	<0.01	5.5	218	421
UF-5-2	08/08/84	1130	2.4	0.02	22	0.03	<0.01	5.9	448	56

STATION NAME	DATE	TIME	SODIUM, DISS., (MG/L)	SODIUM ADSORP-TION RATIO	PERCENT SODIUM	POTAS-SIUM, DISS., (MG/L)	SUL-FATE, DISS., (MG/L)	CHLOR-IDE, DISS., (MG/L)	FLUOR-IDE, DISS., (MG/L)	CYANIDE TOTAL (MG/L)
UF-1-1	08/07/84	0755	1260	37	92	9.7	2570	177	1.9	0.005
UF-1-2	08/07/84	0915	2280	27	78	19	5880	363	1.1	<0.001
UF-1-4	08/07/84	1110	3990	24	63	15	11000	630	1.6	<0.001
UF-3-2	08/08/84	0830	2590	20	64	17	7510	585	0.5	0.003
UF-4-3	08/08/84	0945	1230	11	51	7.8	4560	183	0.4	0.002
UF-5-2	08/08/84	1130	1060	13	63	12	3360	160	1.4	0.002

TABLE 6.4-17

LABORATORY WATER QUALITY DATA (Continued...)
FOR THE RETENTION DAM WELLS

STATION NAME	DATE	TIME	SULFIDE TOTAL (MG/L AS S)	BORON, DISS (UG/L)	ALUM-INUM DISS (UG/L)	ARSENIC DISS., (UG/L)	BARIUM, DISS., (UG/L)	BERYL-LIUM, DISS., (UG/L)	CADMIUM DISS., (UG/L)	CHRO-MIUM, DISS., (UG/L)
UF-1-1	08/07/84	0755	<0.2	580	12	<1	<100	<5	<0.1	<1
UF-1-2	08/07/84	0915	<0.2	580	9	<1	<100	<5	<0.1	<1
UF-1-4	08/07/84	1110	<0.2	1050	65	<1	<100	<5	<0.1	<1
UF-3-2	08/08/84	0830	<0.2	180	56	<1	<100	<5	<0.1	<1
UF-4-3	08/08/84	0945	<0.2	1080	21	<1	<100	<5	<0.1	<1
UF-5-2	08/08/84	1130	<0.2	100	25	<1	<100	<5	<0.1	<1

STATION NAME	DATE	TIME	COPPER DISS., (UG/L)	IRON DISS., (UG/L)	LEAD DISS., (UG/L)	MAN-GANESE, DISS., (UG/L)	MERCURY DISS (UG/L)	MOLYB-DENUM, DISS., (UG/L)	NICKEL, DISS., (UG/L)	SELE-NIUM DISS (UG/L)
UF-1-1	08/07/84	0755	<1	30	<1	30	<0.1	2	3	<1
UF-1-2	08/07/84	0915	5	13400	<1	2020	<0.1	2	<1	<1
UF-1-4	08/07/84	1110	6	18900	<1	550	<0.1	11	17	1
UF-3-2	08/08/84	0830	4	38200	<1	3170	<0.1	2	5	<1
UF-4-3	08/08/84	0945	3	214000	<1	2490	<0.1	1	<1	<1
UF-5-2	08/08/84	1130	4	10100	<1	190	<0.1	3	<1	<1

TABLE 6.4-17

LABORATORY WATER QUALITY DATA FOR THE RETENTION DAM WELLS (Continued...)

STATION NAME	DATE	TIME	SILVER, DISS., (UG/L)	STRON-TIUM, DISS., (UG/L)	VANA-DIUM, DISS., (UG/L)	ZINC, DISS., (UG/L)	GROSS ALPHA DISS., (PCI/L AS U-NAT)	GROSS BETA DISS., (PCI/L AS CS-137)	GROSS BETA, DISS., (PCI/L AS SR90 /Y90)	RADIUM 226, DISS. RADON METHOD (PCI/L)
UF-1-1	08/07/84	0755	<0.2	2460	1	10	<2.0	<10	<5	--
UF-1-2	08/07/84	0915	0.3	12600	1	27	8.0	<10	<5	<0.50
UF-1-4	08/07/84	1110	0.3	16700	1	58	31	<10	<5	<0.50
UF-3-2	08/08/84	0830	0.4	6600	<1	42	<2.0	<10	<5	--
UF-4-3	08/08/84	0945	<0.2	7800	<1	30	<2.0	<10	<5	--
UF-5-2	08/08/84	1130	<0.3	10600	<1	27	<2.0	55	<5	--

STATION NAME	DATE	TIME	URANIUM DISS. DIRECT FLUORO-METRIC (PCI/L)
UF-1-1	08/07/84	0755	--
UF-1-2	08/07/84	0915	--
UF-1-4	08/07/84	1110	67
UF-3-2	08/08/84	0830	--
UF-4-3	08/08/84	0945	--
UF-5-2	08/08/84	1130	--

Undifferentiated Uinta Formation (UNDIF) The two wells, UF-4-3 and UF-5-2, penetrating the Undifferentiated Uinta Formation exhibited the same general water quality characteristics. The ground water from both wells was a sodium-sulfate type with total dissolved solids ranging from 5040 mg/l for UF-5-2 to 6950 mg/l for UF-4-3. This characterization is similar to the ground water in the Birds Nest Zone on the eastern portion of the tracts and surface runoff for Plant Site Wash and Evacuation Creek.

Parameters which exhibited unusually high concentrations included boron, iron, manganese and strontium. An iron concentration of 214,000 ug/l was detected in well UF-4-3 and is believed to be a result of contamination from the iron casing.

Grey Marlstone Unit (GMU) The results of the water quality analysis for wells UF-1-4 and UF-3-2 indicated water extremely high in total dissolved solids. Well UF-1-4 had a TDS value of 16,600 mg/l and well UF-3-2 a value of 11,900 mg/l. Both wells contained a sodium-sulfate type water.

The ground water sampled from the wells also contained measurable levels of boron, copper, iron, manganese, molybdenum, nickel, strontium and zinc. A gross alpha reading of 31 pci/l was also observed for UF-1-4 with a uranium value of 67 pci/l.

Near Surface Porous Zone (NSPZ) All wells completed in the NSPZ were dry or nearly dry, consequently, no water quality samples were collected.

Intermediate Zone (IZ) Well UF-1-2 exhibited a sodium-sulfate type water with a TDS value of 8710 mg/l. The zone also exhibited high values of calcium, magnesium and chloride. Trace materials which were also detected in measurable quantities included boron, iron, manganese, and strontium.

Lower Uinta Gradational Zone (LGZ) Of all of the retention dam wells, UF-1-1 had the lowest TDS with 4050 mg/l. The water was a sodium-sulfate type, however, the water contained significantly lower concentrations of calcium and magnesium than the other wells. Concentrations of trace constitutents such as boron and strontium were similar to other wells, however, iron and manganese were significantly lower with concentrations of 30 ug/l/.

The concentrations of sodium and and sulfate closely follows what would be expected of water percolating through the Uinta Formation and dissolving sodium sulfate (thenardite - Na_2SO_4). This also follows what has been observed in the Birds Nest Zone in the southeast portion of the tracts Ua and Ub. Consequently, the water quality characteristics of the ground water found in the retention dam wells is consistent with the hydrogeochemistry of the Uinta Formation.

Plant Site Alluvium Well AG-10, which was the only well completed in the Plant Site Alluvium, was dry and consequently, no water quality samples were collected.

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Chapter 7.0

7.0 RECLAMATION/VEGETATION RESEARCH

7.0 RECLAMATION/VEGETATION RESEARCH

7.1 INTRODUCTION

Reclamation research during 1984 was a combination of several ongoing studies and the initiation of study exposing plant material to different SO_2 concentrations. Each study is directed to one or several of the "questions to be answered" itemized in the 1982 White River Shale Oil Corporation Environmental Monitoring Manual (EMM) (Sections 3.1 & 7.2.3).

In the vegetation monitoring program litter fall and sagebrush leader growth were selected to monitor the effects of possible increases in SO_2 levels. The sensitivity of those parameters to anticipated levels of atmospheric SO_2 has not been quantified. An SO_2 fumigation study was conducted during 1984 on four vascular plant species and one non-vascular species native to oil tracts Ua and Ub. The objective of the study was to first, document that sagebrush, the vascular species being used in the vegetation monitoring program, is indeed sensitive to increased levels of SO_2, and second to determine the most appropriate technique(s) for measuring its response to increased levels of atmospheric SO_2.

A study was initiated in 1983 and continued in 1984 on the topsoil storage pile near the mine services building. The objective of the study is to identify any changes in soil microbiology that may occur with long tern storage and to evaluate methods of stabilizing soil storage piles while maximizing the soil microflora. From another study started in 1981, an assessment is being made of various methods for enhancing wildlife habitat on areas adjacent to the plant site and processed shale disposal areas.

This study was repeated with some modifications in 1983. Other evaluations conducted during 1984 were ongoing studies. These include the processed shale plant succession study started in 1981; soil analysis indicating plant tolerance levels and salt buildup not in its fifth year; and plant establishment plots both on disturbed areas and processed shale, started in 1979.

The reclamation research completed to date has provided information pertinent to the revegetation of disturbed areas and of processed shale (Van Epps and McKell, 1976, 1978, 1980; McKell, 1978, 1980). Numerous plant species have been identified and methodologies tested that will provide valuable direction in meeting the criteria for successful revegetation for oil shale tracts Ua and Ub (McKell, 1978, 1980; Richardson and McKell, 1979, 1980, 1982; Van .pps and McKell, 1978, 1980; Institute for Land Rehabilitation, .979; Barker and McKell, 1979; Richardson, et al., 1981; Call and McKell 1982; Wagenet et al., 1982).

7.2 PROGRAM SUMMARY

7.2.1 Migration of Salts in Soil Trenches

Analysis of the soil filled trench at Anvil Points followed the format used previously. Differences in pH, EC and elemental content were apparent between soil and shale at various levels as determined by ANOVA and LSD mean separation tests. The surface topsoil sample was significantly higher than the other topsoil samples for pH, but was not significantly different from the surface shale sample. Other topsoil samples tended to have samples for pH, but was not significantly different from the surface shale sample. Other topsoil samples tended to have significantly lower pH and EC values than the shale samples. In 1983, after three years since its establishment, changes in the pH appeared to be increasing consistently. However, the 1984 data showed a drop in pH to roughly 1982 levels. The values for EC exhibit no such increase, indeed the values for 1984 are generally less than previous years, particularly for the surface shale sample.

7.2.2 Plant Establishment Studies

From October 1983 to October 1984, nine plants were lost at the Anvil Points study site. In the soil trenches seven plants died: three seepweed (*Suaeda fruticosa*), one western wheatgrass (*Agropyron smithii*), and three shadscale (*Atriplex confertifolia*). One shadscale plant died in the soil-shale microenvironment study area, and one shadscale died from the flat plantings. Percentage survival of the species used in the trench plantings, basin plantings and flats plantings as of June 1984 are as follows: fourwing saltbush (*Atriplex canescens*) 96%; shadscale 58%; cuneate saltbush

(A. cuneata) 81%; western wheatgrass 92%; greasewood (Sarcobatus vermiculatus) 100%; prostrate kochia (Kochia prostrata) 60%; and seepweed from trench plantings on 29%. Both plant heights and cover values were higher in 1983 indicating that growth continued in the sixth year of the experiment.

7.2.3 Topsoil Stockpile Study

A second phase of the topsoil storage pile study was initiated in 1983. The study was designed and installed at the actual topsoil storage pile near the mine services building. The previous pile was at section 6 and was very limited in size. Treatments at the new site consisted of two different seed mixes, two fertilizer regimes, three replications of each treatment combination, plus control. The plots were sampled for total bacteria, total fungi, respiratory activity, dehydrogenase activity, and percent soil moisture in June and October of 1984. Vascular plant densities were also sampled in October of 1984. Analysis of variance showed significant differences between densities for the different seed mixes with the shallow rooted plots having the highest average density of 24 plants/m^2 while the deep rooted mix averaged 15/m^2 and the control or nonseeded areas averaged 5/m^2. There was no difference due to fertilizer.

The results for the topsoil samples show that there were differences among the treatments, among sample depths and between the June and October samples. The differences in the June and October samples are consistent with those annual fluctuations that are documented in the vegetation monitoring section (3.4.). Differences in treatments were noted for only moisture and respiration. In both cases the control sites were lower than the other treatments. There were significant differences for moisture,

respiration and dehydrogenase among the various depths sampled. Fungi and bacteria showed no significant differences among the various depths sampled. As the vegetation becomes established and roots penetrate in the pile differences will be anticipated.

7.2.4 Interseedings and Interplanting for Wildlife Habitat Enhancement

Two areas, one with substantial annual plant cover and one with less than 5% annual plant cover, were seeded with a standard shrub/grass mix in October of 1983. Seed application was tested using both drill and broadcast techniques. There was a good number of seedlings observed in the drill seeded area in June 1984. By fall, 1984 very few were observed in the entire seeded area and none were found in broadcasted plots.

Transplants of big sagebrush (*Artemisia tridentata*), fourwing saltbush, shadscale, and rubber rabbitbrush (*Chrysothamnus nauseosus*) were also planted in both areas (high and low annual plant cover). The transplants were monitored twice in 1984 in June and October. In June of 1984 plants of all four species were found alive on the Vexar treatment although survival percentages varied. Survival on the Vexar site averaged 72% while the no Vexar treatment had only 6% survival. Most plants continued to survive until October of 1984 with survival on the Vexar treatment averaging 61% and the no Vexar averaging 3%. The greatest cause of mortality was primarily due to rodents and rabbits and not drought.

Sagebrush had the best survival averaging 95% in the Vexar plots followed by rabbitbrush with 88%, fourwing saltbush with 73% and finally shadscale with 55%.

7.2.5 Sensitivity of Native Plant Species to Air Pollution

Sagebrush, rabbitbrush, fourwing saltbush and Utah juniper (*Juniperus osteosperma*), all vascular plants common to the oil shale tracts, and *Lecanora peltata*, a foliose saxicolous lichen species were evaluated for sensitivity to five different levels of SO_2 (0 5, 1.0, 2.0, 3.0, 4.0 ppm) at exposure periods of 2 days, and (0.1, 0.2, 0.4, 0.8, and 0.0 ppm) for the 30-day experiment. Several techniques were used to assess the condition of each of the species following exposure to SO_2. The techniques used included a visual assessment, chlorophyll analysis of the exposed plant material, transpiration, photosynthesis and membrane permeability of the lichen species. It was found that *L. peltata* showed sensitivity after exposure to 4 ppm of SO_2. This is not an indication of actual level of sensitivity of this species. SO_2 levels within the WRSOC project area during 1984, were 0.002 ppm, for the peak three-hour average which is considerably below the test level. Since the 24 hour NAAQS is 0.14 ppm, during operations emissions would be controlled to not exceed these standards. Fumigation conditions did not permit the regulation of humidity and it is known that lichen thalli is most sensitive under higher humidities. Under normal conditions on the oil shale tracts, the measurement of chlorophyll content of *L. peltata* may not be as good an indicator of the condition of the lichen community as would other methods not being used (i.e. lichen cover and number of species per quadrat).

When the four vascular plant species were exposed to 0.5 ppm SO_2 for a 48-hour period, sagebrush, rabbitbrush, and Utah juniper showed significant visual damage, decreases in leaf chlorophyll content, and a decrease in transpiration and photosynthesis. Fourwing saltbush did not show any

adverse effects after exposure to SO_2 for 48 hours.

The three species found to be sensitive after two days exposure were exposed to 0.4 ppm SO_2 for a period of 30 days. All three species showed a negative response to the levels of 0.4 ppm SO_2 used in this experiment.

It was also determined that the chlorophyll a/b ratio and the amount of chlorophyll a per gram of leaf material on a wet weight basis were the two most sensitive techniques for measuring the response of the four vascular plant species to SO_2. Sagebrush and rabbitbrush were found to be the most sensitive species. Visual damage and chlorophyll a/b levels as low as 0.4 ppm in the 30 day experiment and 0.5 ppm in the 2 day experiment.

The results of this research confirms the use of sagebrush as the key vascular plant species to monitor on the tracts. Even though rabbitbrush shows equal sensitivity to SO_2, other factors such as high palatability and scarcity on the tracts suggest that sagebrush should continue to be monitored and used as a key monitoring species.

7.3 PROGRAM DESCRIPTION

7.3.1 Objectives

The objective of the reclamation/vegetation research is to provide data that: (1) describes the possible effects of oil shale mining activities on the vegetation and (2) can be used for the ultimate development of a successful revegetation plan for oil tracts Ua and Ub. Several secondary objectives have directed the efforts in reclamation research. These include the:

- characterization of processed shale relative to its reclamation potential;
- quantification of plant response to environmental impacts created by development;
- determination of the tolerance and response of various plant species to disturbed areas and processed shale for reclamation and enhancement of wildlife habitat;
- development of plant establishment methods for processed shale disposal areas and disturbed sites; and
- measurement of the response of microbial activity in topsoil storage piles to long term storage.

7.3.2 Study Site Locations

Reclamation research has been conducted at several sites on or adjacent to oil shale tracts Ua and Ub since the acquisition of baseline data in 1975. Since that time, two areas have been designated for ongoing research studies. One is at Anvil Points, Colorado, and the other at Section 6 near Bonanza, Utah. The layout of both study sites has been presented in

previous reports (see the 1980 final report (Native Plants, Inc., 1981) for the field plot designed and layout at Anvil Points and the 1982 report (WRSOC, 1983) for studies at Section 6).

The fumigation study was conducted cooperatively between NPI and the Statewide Air Pollution Research Center at Riverside, California. Plant material was analyzed for chlorophyll content and long term visual damage in the laboratories and greenhouses of NPI.

7.3.3 Methodology

A. Reclamation research at Anvil Points, Colorado on and adjacent to the oil shale tracts Ua and Ub has been conducted as outlined in the EMM (Section 7.2). Reference to vascular plant species in tables is occasionally done by referring to the plant species by the commonly used four letter plant symbol as given in USDA Forest Service General Technical Report INT-83. The four letter symbols also correspond to the six letter symbols used in Table IV-1 of the Final Environmental Baseline Report for the White River Shale Project.

B. Sensitivity of native plant species to air pollution.

Plant material - Four vascular plant species and one non-vascular plant all native to the oil shale tracts were used in the fumigation study. Vascular species used were gallon container stock of sagebrush, rabbitbrush, fourwing saltbush, and Utah juniper. The plant material was hardened for a period of 5 weeks prior to the experimentation to insure that changes observed during the experiment were not attributable to transfer shock. Prior to initiation of the experiment all decadent plant material was removed from each plant so confusion could not occur later with SO_2 injury.

Plants were acclimated to the conditions of the fumigation chambers by placing the plant material in the chambers 2 days prior to injection of SO_2. Plants were watered as necessary. Each plant (pot) was marked as to SO_2 level, chamber number and plant number.

L. peltata, a foliose lichen species found commonly throughout the oil shale tracts is the only nonvascular plant selected for the SO_2 study. It is also the key species used in the lichen monitoring program developed for the White River Shale Oil project. The lichen material was collected from the vicinity of the oil shale tracts Ua and Ub in October of 1984. Young lichen thalli and mature lichen thalli were collected and used in the experiment. The lichen material was placed in glass petri dishes and keep in a moisture chamber until experiment initiation.

Fumigation chambers - Open top chambers were used for the experiment. Each chamber was of the standard design used for the United States Environmental Protection Agency's National Crop Loss Assessment (NCLAN) program (Heck, et al., 1982). The chambers were cylindrical, 3 m in diameter and 2.43 in height. The frame was of rolled alluminum and the covering was of clear polyvinylchloride film. The cylinder was divided into an upper half covered by one layer of film and a lower layer covered by an inflatable double layer of film. The inner wall of the lower chamber was covered by 0.03 m diameter holes, positioned in 6 rows, with 0.15 m between rows and between holes within rows. The chamber had a cone-shaped baffle at the top to reduce entrance of ambient air into the chamber. Each chamber was equipped with a blower assembly, 3.4 hp ILG propeller fans, fiberglass particulate filter, corrugated activated charcoal filter, and vinyl duct

between blower box and chamber. All filters were changed prior to the start of each experiment and the film was cleaned to allow maximum radiation.

Sulfur dioxide was injected into the vinyl duct from teflon tubing leading from a thermostated tank (38°C) of pure pressurized liquid SO_2 concentrations. Two chambers did not receive SO_2. Actual SO_2 concentrations in the chambers were constant as measured with a Thermo Electron Company pulsed fluorescent SO_2 analyzer. On a typical day (11/6/84), SO_2 over 24 one hour periods averaged 0.096 + 0.006, 0.119 + 0.009, 0.424 + 0.016 and 0.814 + 0.030 in the 0.1, 0.2, 0.4 and 0.8 ppm SO_2 treatments, respectively. Sulfur dioxide concentrations were recorded throughout the experiment on strip chart recorders. All chambers received filtered air from the blowers, and, thus, the plants were not exposed to any ambient oxidants. The exposures were continuous except during period of rain.

Experimental Design. The duration of the exposure of the plant material to SO_2 was set at 2 days and 30 days. The 2 day exposure was selected to simulate a situation in which high levels of SO_2 would be released into the atmosphere, but most likely for a relatively short period of time. The SO_2 levels used in the 2 day experiment were 0 ppm (a control), .5 ppm, 1 ppm, 2 ppm and 5 ppm, which are levels well above the national annual standard of 0.03 ppm (NAAQS) or 24 hour standard of .14 ppm and would only occur under a plant malfunction.

The 30 day experiment was used to simulate a long term situation in which plant material was exposed to lower levels of SO_2 but for a longer period of time. The SO_2 levels used were 0 ppm (control), .1 ppm, .2 ppm, .4 ppm and .8 ppm.

The two experiments were run separately because of the limited number of chambers available. The 2 day experiment was conducted during the week of October 8 and the 30 day experiment from November 5, through December 5.

The 2 day fumigation study was designed to evaluate the sensitivity of sagebrush, rabbitbrush, fourwing saltbush, Utah juniper and L. peltata to 4 different relatively high levels of SO_2 level including the control. Seven plants of each vascular species and 10 of each lichen life form (mature and old) were randomly placed in each chamber.

The 30 day experiment was essentially the same as the 2 day experiment except only 3 species were tested, sagebrush, rabbitbrush, and Utah juniper. Fourwing saltbush was found to be insensitive to SO_2 level used in the experiment as has been the experience of others (Thompson et al., 1980) and therefore was not tested in the 30 day experiment. The only other variation was the use of 8 plants of each species for the 30 day experiment rather than 7.

Measurements of Plant Sensitivity

Leaf Injury (Visual). Within 48 hours of termination of the SO_2 exposure period each plant was rated for visual injury symptoms. Descriptive comments regarding injury were made as well as a quantitative visual rating of percent leaf area injured in increments of 0, 1 (trace of injury), 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%. The same rating occurred approximately 30 days after the exposure period to assess plant recovery or chronic conditions.

Transpiration. Transpiration was measured 24 hours after SO_2 injection during the 2 day experiment and at 15 days and 30 days during the 30 day experiment. Lambda Instruments Corporation steady state porometer Model

LI 1600 was used to measure transpiration. The porometer was equipped with a cylindrical cuvette which measured humidity changes over a 30 second period. Immediately after measurements were made the twig enclosed by the cuvette was removed and placed in a plastic bag for determination of leaf area (2 sided) with a Lambda Instruments Corporation LI 3100 leaf area meter.

Photosynthesis. Net photosynthesis was measured at the same time transpiration was with a ^{3}H-^{14}C dual isotope porometer (Adams et al. 1977). Each leaf received a 20 second pulse of labeled $^{3}H_2O$ and $^{14}CO_2$. Leaves were extracted in methanol and leaf area (2 sided) was determined after extraction.

Chlorophyll. Within 48 hours of termination of the 2 day and 30 day experiment leaf material from each plant was removed, placed in an correspondingly marked plastic bag and returned to the laboratory for chlorophyll analysis. Transfer from the field to the lab was done with coolers containing dry ice to reduce the possibility of the breakdown of chlorophyll (Harborne, 1973). All plant material was placed in a freezer until chlorophyll extractions were done. Chlorophyll extraction was accomplished by first weighing a representative amount of leaf material taken from that previously collected and placing it in a 25 mm x 150 mm test tube containing 10 ml of 80% acetone saturated with $NaCO_3$ (Holden, 1965; Nash, 1983). The tube is then placed in a closed container ice bath until it is mascerated using a Techmar tissuemizer at full speed for 30 seconds. The mascerated tissue mixture is centrifuged for 10 minutes at 1500 rps and returned to the icebath until wavelength readings are taken on the supernatant using a Beckman DU-6 spectrophotometer at 645 nm, 663 nm and 652 nm. From those readings total chlorophyll, chlorophyll a, chlorophyll b, and Chlorophyll

and chlorophyll a/b ratio were determined on a fresh weight basis (Harborne, 1983).

The same readings on a dry weight basis were calculated by first determining the percent moisture of the leaf material clipped from each plant. This was done by weighting leaf material from each plant, placing it in a drying dish for 8 days at room temperature, and then reweighing the material to determine the loss of weight due to moisture. The percent moisture figure is then used to adjust the fresh weight of the leaf material used for chlorophyll extractions to represent a chlorophyll value/dry weight.

Membrane Permeability. Ten of the 20 lichen specimens of each life form group were removed from the two day SO_2 fumigation chambers and returned to the lab and analyzed for cell membrane leakage following methods outlined by Pearson & Henriksson (1981). Each specimen was placed in 50 ml of distilled water of which the EC had been determined previously. The lichen thalli remained in the distilled water for three minutes, at which time it was removed and the change in the EC of the distilled water determined using a Sybron-Barnstead Model PM70CB conductivity bridge. The change EC is a measure of the leakage of intracellular electrolytes, primarily potassium.

7.3.4 Quality Assurance/Quality Control Precautions were taken to assure that the quality of the research conducted would meet those guidelines outlined in the EMM (Section 3.3.1 and 3.3.2). In some cases, the scope of the project was simplified to allow adequate sampling and greater confidence of the results. All reclamation/revegetation research studies

were set up and conducted to test one of several hypotheses detailed in the EMM (Sections 7.1.3 and 7.2.3).

Soils analysis was the area for most concern in the QA/AC program. To assure quality, duplicate samples were anlayzed on selected soils. Also, soils were analyzed by only certified labs. Sample handling is important in the topsoil microbiology samples, since heat and time will create an incubation of the organism (bacteria and fungi) and artifically increase their numbers. This is what occurred with the 1981 samples. The samples will be cooled within a few minutes of being taken and kept in cold storage (walk in refrigerator) until analysis. Analysis begins as soon as the soils are received in the lab to also reduce any incubation time.

Soil analysis methods are standardized, yet there is often considerable variation when analyzing for particular elements. This suggests that the variability is in the soil matrix and care must be taken in deriving conclusions about differences in elements with high variability.

Several quality control measures were taken during the SO_2 fumigation study to assure an accurate assessment of each plant species to the different levels of SO_2. All fumigation chambers were equilibrated for 2 days prior to each experiment. SO_2 concentrations for each chamber were recorded on strip charts each hour during the equilibration period and during the experiment. Any perturbations observed in SO_2 concentration were quickly adjusted. The experimented design employed replicates of both the number of plants used per chamber and the number of chambers per SO_2 level to reduce the variation between plants and to assess between chamber variation, if any.

Several precautions were taken when analyzing the plant material for chlorophyll. As mentioned in the methods section, once the plant material was clipped form each plant it was placed in a cooler containing dry ice and transported to a freezer in the laboratory until chlorophyll extractions were conducted. During the extraction process ice baths were used and plant material and extractions were kept in an enclosed container to minimize exposure to light. Both precautions were taken to ensure an accurate determination of chlorophyll content by reducing chlorophyll breakdown to phaeophytins due to exposure to light and higher temperatures.

Although detailed procedures were followed to determine chlorophyll content of the plant material two preliminary samples were run to calibrate the equipment and adjust the procedures to the specific experiment.

7.4 PROGRAM RESULTS AND ANALYSIS

7.4.1 Migration of Salts

Studies initiated in 1979 at Anvil Points established a top soil fill trench in a shale disposal pile. The survival of species transported into the soil trenches in this experiment has been monitored since 1979. Beginning in 1981, soil samples were collected from various depths in the soil trench and adjacent shale and were analyzed for pH and EC.

Detailed analysis of pH and EC were performed for the 1981-1984 period on the Anvil Points trenches. The summary table for pH is shown in Table 7.4-1. There was a sustained increase in pH from 1981-1983 but the 1984 readings are lower than the 1983 values. The 1984 figure is well within the tolerance levels for all the species growing in the trench and it would appear that the pH may level off in future years. The ANOVA also showed significant differences among the depths sampled. The pH of the topsoil samples were all significantly lower than the shale samples. The pH of the topsoil samples were all significantly lower than the shale samples, with the exception of the surface samples. The pH of the topsoil surface has increased and in 1984 was not significantly different from the surface shale samples. The topsoil surface was significantly different from the other topsoil samples.

The two-way ANOVA for EC showed that there were no significant differences between years. The 1984 average was the lowest of the years sampled (Table 7.4.2). There were significant differences between depths with the topsoil samples having lower EC values than most of the shale

Table 7.4-1 pH values from different depths in the topsoil trench study at Anvil Points for the period from 1981-1984. Values followed by common letters are not significantly different as tested by ANOVA and Fisher's LSD (F-value $\leq$ .005, $\alpha \leq$.05)

Sample depth	1981 June $\bar{x}$	1981 October $\bar{x}$	1982 June $\bar{x}$	1983 June $\bar{x}$	1984 June $\bar{x}$
0-2 cm topsoil	7.90	7.85	8.08	8.60	8.29[b]
15 cm topsoil	7.41	7.69	7.78	8.35	8.07[a]
30 cm topsoil	7.52	7.64	7.76	8.25	7.99[a]
45 cm topsoil	7.61	7.89	7.89	8.33	7.97[a]
0-2 cm shale	8.72	8.70	8.55	8.70	8.31[bc]
15 cm shale	8.11	8.51	8.50	8.67	8.49[cd]
60 cm shale	8.14	8.51	8.70	8.77	8.65[d]
Average	7.92[a]	8.11[a]	8.18[b]	8.53[c]	8.25[b]

ANOVA Table for 1981-1984 for pH

S.O.V.	df	S.S	M.S.	F-value
Year (1)	4	1.38	0.35	12.27*
Depth (2)	6	3.35	0.56	19.92*
Error	24	0.67	.03	
Total	34			

*significant at $\alpha \leq$ .005.

ANOVA Table for 1984 for pH

	df	SS	M.S.	F-value
Depth	6	1.61	.27	4.45**
Error	21	1.27	.06	
Total	27	2.88		

**significant at $\alpha \leq$ .05

Table 7.4-2 Electrical conductivity (EC) values sampled from different depths in the topsoil trench at Anvil Points for the period from 1981-1984. Values followed by common letters are not significantly different as tested by ANOVA and Fisher's LSD (F-value $\leq$ .01, $\alpha \leq$ .05)

Sample depth	1981 June $\bar{x}$	1981 October $\bar{x}$	1982 June $\bar{x}$	1983 June $\bar{x}$	1984 June $\bar{x}$	1981-1984 $\bar{x}$		
0-2 cm topsoil	4.4	3.1	1.9	1.9	1.0	2.8^{a}	2.5^{a}	12.3
15 cm topsoil	2.0	2.9	3.4	3.2	2.4	2.9^{a}	2.8^{a}	13.9
30 cm topsoil	3.0	4.4	4.8	3.0	5.3	3.8^{ab}	4.1^{ab}	20.5
45 cm topsoil	3.7	7.5	5.1	5.0	5.7	5.3^{ab}	5.4^{abc}	27.0
0-2 cm shale	16.7	14.6	17.9	14.1	2.2	15.8^{c}	13.1^{d}	65.5
15 cm shale	4.5	12.7	8.9	5.5	1.6	7.9^{b}	6.6^{bc}	33.2
60 cm shale	6.2	12.5	7.2	8.1	7.6	8.5^{b}	8.3^{c}	41.6
$\bar{x}$	5.8^{a}	8.2^{a}	7.0^{a}	5.8^{a}	3.7^{a}			

ANOVA table for EC for years 1981-1984

S.O.V.	df	S.S.	M.S.	F
Years	4	80.18	20.05	2.47
Depths	6	414.90	69.15	8.51*
Error	24	195.12	8.13	
Total		690.20		

*significant at α < .01.

samples. The surface shale sample which was extremely high in 1983 averaging 15.8 mmhos/cm^3 had a dramatic decline to only 2.2 mmhos/cm^3. The topsoil EC values are well within the range of tolerance for species that would be used for reclamation.

The general trend with time appears to show an initial increasing salt level then a leveling off. This is shown by the increase of pH from 1981 to 1983 with a decline in 1984. The other measure of salts, EC, showed no significant increases among years.

7.4.2 Plant Establishment Studies

Studies have been conducted since early 1976 to evaluate various techniques that can be used to establish plants in oil shale disposal areas. The information collected in 1874 from each study area includes height, cover, and survival of each planting.

Evaluation of Plantings at Anvil Points, Colorado.

The six different plantings on the shale disposal pile at Anvil Points were evaluated in June 1984. The height and cover of each living plant was recorded (Table 7.4-3). Mortality in addition to previous observations was also noted. Only nine plants of the 184 still alive in 1983 died for a loss of 5%. Five shadscale plants were lost during the 1984 growing season. Three were in the soil trenches, one in the flat planting and one in the soil-shale microenvironment study. One species suffered a single loss, western wheatgrass in the topsoil trench study area, while seepweed had three die in the topsoil trench. The percent survival of each species at each study site for years 1979-1984 is given in Table 7.4-4. In the soil trench plantings, fourwing saltbush, and greasewood show 100% survival.

Table 7.4-3 Plant height and cover estimates. Cover estimated by counting top number of 1 dm^2 grids occupied by each plant. Cover values represent the number of grids occupied by the plant. Height is in cm. Anvil Points, Colorado. June 1984.

NORTH SOIL TRENCH

	ATCA		ATCO		ATCU		AGSM		SAVE		KOPR		SU spp.	
	Fourwing Saltbush		Shadscale		Cunneate Saltbush		Western Wheatgrass		Greasewood		Prostrate Kochia		Seepweed	
Replication	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover
											M	M		
II	101	20	32	30	22	3	70	85	164	95			M	M
III	70	30	27	15	32	55	75	60	130	45	M	M		
IV	80	24	M	M	M	M	64	40	114	115			M	M
V	46	8	19	7	28	3	60	50	71	50	32	6		
VI	82	40	17	3	26	35	42	40	71	45			M	M
VII	58	4	13	1	26	3	53	45	98	60	12	18		
VIII	103	70	18	3	28	20	66	40	140	70			M	M
IX	92	30	18	6	112	6	68	20	138	90	M	M		
X*									105	85	4	9	M	M
XI									160	70				
Average	79	28	21	9	39	18	62	48	119	73	16	11	0	0
Standard Deviation	20	21	7	10	32	20	11	19	33	23	14	6	0	---

SOUTH SOIL TRENCH

I							68	220						
II	95	55	23	3	M	M	68	200	158	115			M	M
III	86	12	M	M	44	18	79	70	110	50	60	60		
IV	103	75	33	7	32	13	77	30	145	85			M	M
V	106	80	32	8	25	22	85	35	120	75	M	M		
VI	37	4	16	6	31	38	M	M	135	50			63	30
VII	65	30	17	3	24	7	65	30	37	40	40	15		
VIII	94	40	M	M	M	M	72	35	130	100			28	2
IX	54	10	M	M	29	25	79	45	93	40	43	13		
X*									137	95				
Average	80	38	24	5	31	19	74	83	118	72	48	29	46	16
Standard Deviation	25	30	8	2	7	8	7	80	36	28	11	27	25	20

Table 7.4-3 Continued

Replication	ATCA Fourwing Saltbush Height	ATCA Fourwing Saltbush Cover	ATCO Shadscale Height	ATCO Shadscale Cover	ATCU Cuneate Saltbush Height	ATCU Cuneate Saltbush Cover	AGSM Western Wheatgrass Height	AGSM Western Wheatgrass Cover	SAVE Greasewood Height	SAVE Greasewood Cover	KOPR Prostrate Kochia Height	KOPR Prostrate Kochia Cover	SUFR Seepweed Height	SUFR Seepweed Cover
BASIN PLANTINGS														
I	55	30	M	M	31	35	64	12	90	30			M	M
II	90	45	M	M	16	2	75	10	87	45			M	M
III	62	5	M	M	M	M	72	8	105	40			M	M
IV	110	90	M	M	12	1	79	5	86	45			M	M
V	M	M	M	M	M	M	M	M	23	2			M	M
Average	79	43	M	M	20	13	73	9	78	32			M	M
Standard Deviation	25	36			10	19	6	3	32	18				
FLAT PLANTINGS														
I	48	15	25	7	31	30	57	2	32	5			M	M
II	119	60	19	5	37	35	41	1	42	9			31	18
III	69	35	34	20	41	35	45	1	79	20			36	4
IV	81	35	M	M	35	25	56	2	83	30			M	M
V	58	18	M	M	42	60	61	3	76	55			M	M
Average	75	33	26	11	37	37	52	2	62	24			34	11
Standard Deviation	28	18	8	8	4	14	9	1	24	20			4	10

Table 7.4-3. Continued

EAST FENCE

Replication	SAVE Greasewood Height	SAVE Greasewood Cover	ATCA Fourwing Saltbush Height	ATCA Fourwing Saltbush Cover	HAHA Siberian Salt-tree Height	HAHA Siberian Salt-tree Cover	ATCO Shadscale Height	ATCO Shadscale Cover	ARTR Big Sagebrush Height	ARTR Big Sagebrush Cover	ATGA Gardners Saltbush Height	ATGA Gardners Saltbush Cover
I	74	40	98	30	4	<1	37	24	M	M	24	32
II	43	30	36	5							25	30
III	126	45	78	55								
IV	53	35										
Average	74	38	71	30	4	<1	37	24	M	M	25	31
Standard Deviation	37	6	32	25	0	0	0	0			1	1

SOUTH FENCE

I	63	25	130	70	69	3	M	M				
II	32	12	65	45			20	4				
III	102	35	154	60			M	M				
IV	23	22	M	M			17	1				
V	71	30	43	40								
VI	59	35	M	M								
Average	58	27	98	54	69	3	19	3				
Standard Deviation	28	9	53	14	0	0	2	2				

e - grown in soil prior to transplanting, all others were grown in spent shale
M - plant mortality
blank - no plantings

Table 7.4-3 Continued

SOIL-SHALE MICROENVIRONMENT

Replication	ATCA Fourwing Saltbush Height	ATCO Shadscale Height	ATCU Cuneate Saltbush Height	AGSM Western Wheatgrass Height	ATCOR Mat Saltbush Height
I	85	M	M	62	M
II	M	37	20	41	16
III	67	39	13	49	M
IV	M	M	28	33	9
V	68	32	9	41	M
Average	73	36	18	55	13
Standard Deviation	10	4	8	23	5

M = plant mortality

Table 7.4-4. Summary of survival of plantings at Anvil Points, Colorado, 1979-1984.

Species	Survival (%) 1979	1980	1981	1982	1983	1984
South Trench Plantings						
ATCA	100	100	100	100	100	100
ATCO	100	90	80	80	80	63
ATCU	100	100	100	80	80	75
AGSM	100	100	100	100	100	89
SAVE	100	100	100	100	100	100
KOPR	67	67	67	67	67	75
SUFR	80	60	60	60	60	66
North Trench Plantings						
ATCA	100	100	100	100	100	100
ATCO	100	90	90	90	90	88
ATCU	100	90	90	90	90	88
AGSM	100	100	100	100	100	100
SAVE	100	100	100	100	100	100
KOPR	50	50	50	50	50	50
SUFR	100	40	40	20	40	0
Basin Plantings						
ATCA	100	100	100	80	80	80
ATCO	100	20	0	0	0	0
ATCU	100	80	60	60	60	60
AGSM	100	80	80	80	80	80
SAVE	100	100	100	80	100	100
KOPR	100	40	20	0	0	0
Flat Plantings						
ATCA	100	100	100	100	100	100
ATCO	100	100	80	80	80	60
ATCU	100	100	100	100	100	100
AGSM	100	100	100	100	100	100
SAVE	100	100	100	100	100	100
KOPR	100	60	60	60	40	40

Table 7.4-4.(Cont.)

Species	1979	1980	1981	1982	1983	1984
			Survival (%)			
Demonstration Study (East Fence)						
ATCA	100	100	100	100	100	100
ATCO	100	100	100	100	100	100
ATGA	100	100	100	100	100	100
ARTR	100	100	0	0	0	0
SAVE	100	100	100	100	100	100
HAHA	100	100	100	100	100	100
Demonstration Study (South Fence)						
ATCA	83	67	67	67	67	67
ATCO	75	75	50	50	50	50
SAVE	100	100	100	100	100	100
HAHA	100	100	100	100	100	100
Soil-Shale Microenvironment Study						
ATCA	100	100	80	60	60	60
ATCO	100	100	100	100	80	60
ATCU	100	100	100	100	80	80
AGSM	100	100	100	100	100	100
ATCOR	100	100	80	80	40	40

Prostrate kochia and seepweed have suffered the greatest overall mortality in the two soil trenches, 75% and 50% respectively in the south trench and 50% and 40% respectively in the north trench.

The basin plantings show the highest mortality of the different establishment techniques tested on the Anvil Points shale disposal site. Greasewood (100%), fourwing saltbush, and western wheatgrass (both 80%) have the highest percentage survival, cuneate saltbush has 60% survival, and shadscale and prostrate kochia 0% survival.

The flat plantings and demonstration study area along the east fence have had very little change in survival since 1981, however, there was a loss of one shadscale this year in the flat planting. Both show high survival rates for all species except big sagebrush (0%) along the east fence and prostrate kochia (40%) in the flat plantings.

The survival of species planted along the south fence as part of the demonstration study did not change from the 1981 results. Along the south fence greasewood and Siberian salt-tree (Halimodendron Halodenfron) show the best survival (100%) and fourwing saltbush and shadscale the worst (67%, 50%, respectively). The soil-shale microenvironment plantings which experienced significant losses in 1983 had only one plant die in 1984.

A summary and analysis of the data for height and cover collected on the plantings at Anvil Points since 1979 is presented in Table 7.4-5. Several species have shown remarkable survival and growth under the various treatments. Fourwing saltbush, cuneate saltbush, western wheatgrass, and greasewood have shown the best survival growth of the species used in the several different studies conducted at Anvil Points. Other species such as

Table 7.4-5. Summary of growth of plantings at Anvil Points, Colorado, 1979-1984. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Comparison of Average
Height (cm) and Cover of Plantings
in South Trench

		1979	1980	1981	1982	1983	1984
Fourwing Saltbush	HT	26.7^{a}	35.6^{a}	56.3^{b}	66.6^{bc}	76.5^{cd}	80.0^{d}
	CVR	----	5.4^{a}	20.0^{b}	25.1^{b}	32.4^{bc}	38.3^{c}
Shadscale	HT	5.8^{a}	8.2^{a}	11.0^{a}	10.9^{a}	13.8^{a}	24.2^{b}
	CVR	----	0.8^{a}	1.2^{ab}	2.4^{b}	2.6^{b}	5.4^{c}
Cuneate Saltbush	HT	14.6^{a}	18.0^{a}	22.1^{a}	21.0^{a}	23.9^{ab}	30.8^{b}
	CVR	----	2.9^{a}	10.4^{ab}	16.6^{bc}	21.4^{c}	19.2^{c}
Western Wheatgrass	HT	22.3^{b}	18.8^{ab}	15.0^{a}	29.0^{c}	41.4^{d}	74.1^{e}
	CVR	----	0.8^{a}	5.7^{a}	17.9^{a}	60.5^{b}	83.1^{b}
Greasewood	HT	25.5^{a}	35.9^{a}	58.8^{b}	71.0^{b}	89.5^{c}	118.3^{d}
	CVR	----	4.7^{a}	19.5^{ab}	32.1^{b}	54.6^{c}	72.2^{d}
Prostrate Kochia	HT	19.8^{a}	13.0^{a}	21.3^{a}	22.3^{a}	19.0^{a}	47.7^{a}
	CVR	----	2.3^{a}	7.5^{a}	10.8^{a}	15.2^{a}	29.3^{a}
Seepweed	HT	13.8^{a}	13.6^{a}	14.4^{a}	18.2^{b}	9.2^{a}	45.5^{a}
	CVR	----	$.6^{a}$	1.1^{a}	1.2^{a}	1.4^{a}	16.0^{b}

Table 7.4-5. (Continued)

Comparison of
Average Height (cm) and Cover
of Plantings
in
North Trench

		1979	1980	1981	1982	1983	1984
Fourwing Saltbush	HT	24.1^{a}	29.9^{a}	54.7^{b}	60.8^{bc}	69.1^{cd}	79.0^{d}
	CVR	----	3.0^{a}	10.7^{b}	14.4^{bc}	20.4^{c}	38.3^{c}
Shadscale	HT	7.5^{a}	8.5^{a}	14.8^{b}	14.1^{ab}	19.1^{bc}	20.6^{c}
	CVR	----	0.7^{a}	1.4^{a}	3.4^{b}	3.8^{b}	9.3^{c}
Cuneate Saltbush	HT	10.3^{ab}	8.8^{a}	15.1^{ab}	16.6^{b}	25.8^{c}	39.1^{d}
	CVR	----	2.3^{a}	8.7^{a}	21.5^{bc}	28.4^{bc}	17.9^{b}
Western Wheatgrass	HT	23.7^{b}	19.9^{ab}	16.2^{a}	33.0^{c}	45.7^{d}	62.3^{d}
	CVR	----	0.7^{a}	7.0^{a}	19.5^{b}	32.8^{c}	47.5^{d}
Greasewood	HT	21.3^{a}	33.1^{b}	61.2^{c}	75.8^{d}	88.8^{d}	119.1^{e}
	CVR	----	4.3^{a}	18.4^{b}	27.0^{b}	45.7^{c}	72.5^{d}
Prostrate Kochia	HT	14.8^{a}	16.0^{a}	33.3^{a}	38.0^{a}	26.7^{a}	16.0^{a}
	CVR	----	1.0^{a}	3.3^{a}	3.7^{a}	3.7^{a}	11.0^{a}
Seepweed	HT	16.3^{a}	16.0^{a}	23.5^{a}	30.0^{a}	23.0^{a}	0.0^{b}
	CVR	----	$.4^{a}$	$.4^{a}$	$.6^{a}$	$.6^{a}$	0.0^{a}

Table 7.4-5. (Continued)

Comparison of
Average Height (cm) of
Flat Plantings

		1979	1980	1981	1982	1983	1984
Fourwing Saltbush	HT	27.8^{a}	36.6^{a}	60.0^{b}	63.6^{b}	69.6^{b}	75.0^{b}
	CVR	----	2.3^{a}	11.6^{a}	14.4^{ab}	28.2^{bc}	32.6^{c}
Shadscale	HT	7.6^{a}	9.2^{a}	8.8^{a}	12.0^{ab}	17.2^{bc}	26.0^{c}
	CVR	----	0.9^{a}	1.3^{a}	4.0^{a}	6.4^{ab}	10.7^{b}
Cuneate Saltbush	HT	12.8^{a}	15.2^{a}	20.6^{b}	27.8^{c}	34.0^{d}	37.2^{d}
	CVR	----	1.8^{a}	8.6^{a}	18.0^{b}	28.6^{c}	37.0^{c}
Western Wheatgrass	HT	19.6^{a}	28.2^{b}	32.2^{b}	33.4^{b}	45.4^{c}	52.0^{c}
	CVR	----	0.5^{a}	1.2^{ab}	1.4^{bc}	2.0^{c}	1.8^{bc}
Greasewood	HT	18.0^{a}	28.4^{ab}	34.4^{bc}	43.8^{c}	50.4^{cd}	62.4^{d}
	CVR	----	1.9^{a}	4.6^{ab}	10.4^{bc}	13.2^{c}	23.8^{d}
Seepweed	HT	17.4^{a}	14.0^{a}	16.2^{a}	23.8^{a}	11.8^{a}	33.5^{a}
	CVR	----	0.8^{a}	2.8^{a}	4.8^{a}	3.4^{a}	11.0^{a}

Comparison of
Average Height (cm) and Cover
of
Basin Plantings

		1979	1980	1981	1982	1983	1984
Fourwing Saltbush	HT	27.2^{a}	33.8^{ab}	63.0^{bc}	65.0^{bc}	57.0^{b}	79.3^{c}
	CVR	----	4.6^{a}	19.0^{a}	41.4^{a}	46.8^{a}	42.5^{a}
Shadscale	HT	5.2^{b}	1.8^{ab}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
	CVR	----	$.2^{a}$	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Cuneate Saltbush	HT	9.0^{a}	9.6^{a}	7.8^{a}	4.8^{a}	11.6^{a}	19.7^{a}
	CVR	----	3.6^{a}	3.0^{a}	5.0^{a}	11.2^{a}	12.7^{a}
Western Wheatgrass	HT	22.0^{a}	18.8^{a}	40.2^{a}	40.6^{a}	57.6^{ab}	72.5^{b}
	CVR	----	$.4^{a}$	1.5^{a}	4.0^{a}	9.0^{b}	8.8^{b}
Greasewood	HT	18.2^{a}	28.4^{ab}	47.0^{bc}	56.2^{c}	66.4^{cd}	78.2^{d}
	CVR	----	2.7^{a}	11.3^{ab}	17.52^{bc}	25.6^{cd}	32.4^{d}
Seepweed	HT	31.2^{a}	14.0^{a}	9.0^{a}	8.2^{a}	0.0^{a}	0.0^{a}
	CVR	----	1.1^{a}	4.4^{a}	$.8^{a}$	0.0^{a}	0.0^{a}

Siberian salt-tree and gardner's saltbush have shown good survival, but have not been tested as extensively as the other species. Big sagebrush and seepweed have shown the poorest survival.

7.4.3 Microbiology and Stabilization of Topsoil Storage Pile

Long-term stockpiling can reduce microbial activities in topsoils making them less suitable as plant growth media (Rives et al., 1980; Williams et al., 1981). Many soil microorganisms are directly or indirectly dependent on living plants for their existence, and the absence of plant roots in much of the stored soil is partly responsible for the loss of these organisms. Soil microbial populations in stockpiles could be maintained to some extent by minimizing the duration of storage, and/or by establishing and maintaining appropriate plant cover on the storage piles. Therefore, seeding of soil stockpiles is not only valuable for erosion control and stockpile stabilization, but also for the maintenance of important soil biological characteristics. The purpose of this study is to evaluate the effect of seeding on the microbiological activity of stockpiled topsoil through time.

The design and installation of the topsoil stockpile study was completed October of 1983. The study is located on the small topsoil pile near the mine services building at the plant site. The treatments consist of two different seed mixes (shallow and deep rooted species, Table 7.4-6), tow fertilizer regimes (no fertilizer and 85 lbs. ammonium nitrate/acre) with three replications of each laid out in completely randomized 9 m x 9 m plots. Three replicates of the control treatment were also identified.

Table 7.4-6. Seed mixes used on topsoil pile soil microbiology study.

Seed Mix A

Deep rooted plants:

Species/Lot #	Rate (lbs/acre)
ARTR/846	1
ATCA/2208	3
ATCO/888	3
CELA/2248	2
CHNA/2022	1
MESA-Ladak/1980	2
PUTR/1627	3
AGSM/2212	2
AGEL/2297	3
HEBO/2330	3
	23 lbs/acre

Seed Mix B

Shallow rooted plants:

Species/Lot #	Rate (lbs/acre)
ERUM/3011	2
LILE/1786	2
SPGR/1632	1
AGDA-Critana/1430	2
AGIN-Greenar/2075	3
AGSM-Arriba/2212	2
AGTR2-Luna/1188	3
BOGR/1984	1
HIJA/1939	2
ORHY/2377	2
	20 lbs/acre

The stockpile had been seeded in the fall of 1982, but the seeding survival was very poor. The plots were flagged in and then lightly rototilled to remove any plants seeded previously and to prepare a suitable seedbed for planting. The seed was hand broadcasted and then the plots were raked to encourage seed burial. Each plot was covered with a straw mulch (a rate of 1.5 tons/acre) which was tacked at a rate of 240 lbs. of Tera Tak AR/acre so the straw would not blow off. The plots were fertilized in spring 1984 after germination had occurred.

In June 1984 and October 1984, soils from the research plots were sampled at a variety of depths and analyzed using the same techniques as were used in the soil microbiology portion of the vegetation monitoring section. The resulting values were compared to those obtained from soils sampled in the control treatments. Also in October, density counts of vascular plants were taken for each plot. Results of these counts are shown in Table 7.4-7.

The analysis of variance showed significant differences among the treatment for plant density. The shallow rooted seed mix with fertilizer had the best density averaging 25.2 plants/m^2 followed by the shallow rooted mix with no fertilizer with 23.1 plants/m^2. The deep rooted seed mixes (fertilized and not fertilized) had significantly less density value at 13.3 and 16.7 plants/m^2, respectively. Finally, the control, non-seeded, had the poorest density at 5.1 plants/m^2.

Analysis of variance performed on the soils data identified two additional parameters that varied significantly among the seed treatments (Table 7.4-8). The first parameter was soil moisture where the control and

Table 7.4-7. Summary of density values on the topsoil pile study. Values followed by common letters are not significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Treatments	Density/m^2
Control	5.13^a
Shallow rooted, fertilizer	25.20^c
Shallow rooted, no fertilizer	23.07^c
Deep rooted, fertilizer	13.33^b
Deep rooted, no fertilizer	16.67^b

Table 7.4-8. Summary table of topsoil pile study by treatment. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Treatments	Moisture (%)	Fungi (m/dry g)	Bacteria ($x10^6$CFU/g)	Respiration (meg $CO_2 x10^{-4}$g/hr)	Dehydrogenase (mg formazan/l)
Control	12.1^a	28.6^a	27.3^a	3.38^a	2.05^a
Shallow, fertilizer	13.4^{bc}	31.1^a	29.3^a	4.01^b	2.89^a
Shallow, no fertilizer	14.0^c	30.3^a	31.4^a	4.21^b	2.17^a
Deep, fertilizer	13.1^b	26.3^a	27.2^a	4.48^b	3.00^a
Deep, no fertilizer	12.1^a	32.9^a	30.9^a	4.21^b	2.97^a

the deep rooted seed mix with no fertilizer had the lowest moisture content averaging 12.1%. The shallow rooted seed mix with no fertilizer had the highest moisture content with 14.0%. The other two treatments were intermediate.

Respiration was the second parameter which showed a significant difference among treatments. The control plots which averaged 3.38 meq CO_2 x 10^{-4} g/hr were significantly lower than all the other treatments (Table 7.4-4). The highest values for respiration were from the deep rooted mix with fertilizer which averaged 4.48 meq CO_2 x 10^{-4} g/hr.

Analysis of variance comparing the influence of depth on the parameters sampled identified three parameters (moisture, respiration and dehydrogenase) that were significantly influenced by depth (Table 7.4-9). Both moisture and respiration showed a positive relationship with increasing depth while dehydrogenase activity decreased with depth. Respiration may be responding simply to the amount of moisture available and not in response to soil depth per se based on the positive correlation between these two factors in the soil microbiology section (Table 3.4-8). Dehydrogenase, on the other hand, appears to be more strongly influenced by depth since it also has a positive correlation with moisture but is responding in the topsoil directly opposite of the moisture gradient.

Fungi and bacteria show no significant differences or even trends among the various sampling depths. Other studies have shown a decrease in microbioal populations in stockpiled topsoil over time at deeper depths (Visser et al., 1984; Ross and Cairns, 1981). Differences should begin to show with the 1985 sampling.

Table 7.4-9. Summary table of topsoil pile study by depth. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Depths (cm)	Moisture (%)	Fungi (m/dry g)	Bacteria ($x10^6$CFU/g)	Respiration (meg $CO_2 x10^{-4}$g/hr)	Dehydrogenase (mg formazan/l)
0- 20	11.7^a	32.2^a	29.2^a	3.74^a	4.44^c
20- 40	12.3^a	27.6^a	30.8^a	3.81^a	2.97^b
40- 60	13.8^b	29.8^a	34.3^a	4.17^{ab}	2.13^{ab}
60- 80	14.3^b	32.3^a	36.3^a	4.30^{ab}	2.06^{ab}
80-100	13.9^b	33.4^a	34.1^a	4.57^b	1.58^a
100-120	14.0^b	27.1^a	27.9^a	4.57^b	1.48^a

There were significant differences for all the parameters, sampled between the June and October sampling dates (Table 7.4-10). Levels for moisture, fungi, bacteria and respiration were all significantly higher in June while dehydrogenase was significantly higher in the October samples. The values for these two sampling dates corresponds to the natural annual fluctuations that are identified in the vegetation monitoring section.

7.4.4 Interseeding and Interplanting Existing Shrub Vegetation

As a means of increasing the wildlife carrying capacity of existing shrub dominated vegetation, interseeding and/or interplanting has been suggested. A study was established in October 1981 to test the hypothesis that scattered interplantings of container grown plants could survive and increase community diversity and productivity. A corollary hypothesis of the study tested direct seeding (drilled and broadcast) to increase diversity and productivity. The study concluded in 1983 with very limited success. A major reason for the failure of the interseeding and interplanting was based on the pressure exerted by an abnormally high rabbit population. The experiment was reinitiated in October of 1983 at the same study site with in the study design made to exclude herbivores. Fencing of the interseeded areas was added as treatment as was placement of Vexar tubing around one half of the transplants.

The transplants included four species, fourwing saltbush, sagebrush, rabbitbrush and shadscale. Twenty plants of each species were planted in each subplot (10 with Vexar, 10 without Vexar). The plants were planted by hand and watered using .3 liters of water per plant. The soil was

Table 7.4-10. Summary table of topsoil pile study by sampling period. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Sampling Date	Moisture (%)	Fungi (m/dry g)	Bacteria ($x10^6$CFU/g)	Respiration (meg CO_2x10^{-4}g/hr)	Dehydrogenase (mg formazan/l)
June 1984	15.1^a	34.1^a	50.4^a	4.80^a	1.63^a
October 1984	11.3^b	26.7^b	14.0^b	3.50^b	3.38^b

moist at the time of planting due to earlier storms. The height of each plant was recorded later comparisons. The seeded areas were hand broadcasted and drill seeded using a hand pushed belt seeder.

The area was revisited 3 days following planting. The transplants that did not have the Vexar treatments had already been severely grazed with the exception of sagebrush. Many had been clipped at ground level and may not resprout. The Vexar appeared to be very worthwhile in deterring herbivroes and would be very cost effective if planting is going to be done in areas or during years with high rodent populations.

To document the effect of rodents on transplant establishment, the survival of the transplants was recorded on November 2, 1983, June 1984 and again in October 1984. The results are reported in Table 7.4-11.

The average survival of transplants with Vexar during the June sampling was 72% while the equivalent value on the no Vexar treatment was only 6%. Animals could be attributed to causing the loss of 66% of the transplants. The October sampling showed the same pattern although a larger perentage of the Vexar protected plants succumbed to the summer stress period reducing the survival to 61% while the non-vexar treatment had only 3% survival.

Sagebrush had the best survival averaging 93% on the Vexar plots. Rabbitbrush had the second best survival (80%), followed by fourwing saltbush (48%) and shadscale (25%).

The study also tested whether annual species influenced transplant survival. The analysis of variance showed no significant difference between the plants with high annual cover and those with low annual cover. Thus,

Table 7.4-11. Survival of transplants at Section 6 for the interplanting study.

Species (With Vexar)	Survival % Oct 83	June 84	Oct 84	(No Vexar)	Oct 83	June 84	Oct 84
ARTRA	100	90	90		100	10	0
C	100	80	80		100	10	10
B	100	100	100		100	0	0
D	100	100	100		100	10	10
ATCAA	100	80	70		100	0	0
C	100	60	40		100	0	0
B	100	70	50		100	0	0
D	100	70	30		100	40	10
ATCOA	100	0	0		100	0	0
C	100	30	20		100	0	0
B	100	50	10		100	0	0
D	100	80	70		100	10	0
CHNAA	100	90	80		100	0	0
C	100	70	70		100	0	0
B	100	80	70		100	0	0
D	100	100	100		100	20	20
Average	100	72	61		100	6	3

controlling annual vegetation would not be required for successfully establishing an interplanting program.

The density of seeded species on the interseeding study at Section 6 is shown in Table 7.4-12. Analysis of variance showed that there was a significant difference only between the methods of seeding with drill seeding having nearly 10 times the number of seedings as broadcast seeding (8.4 and 0.9, respectively). Fencing or density or annual cover did not significantly affect seedling survival. The plots were sampled in June and later in October. The difference in survival between these two sampling periods is dramatic. While the June samples average 4.7 plants overall, the October samples averaged on 0.3 plants. This illustrates the lack of success of direct seeding in these arid environments even with an unusually wet year. The results of this study have shown that interseeding is not a viable alternative in trying to compensate wildlife for plant production lost through developmental activities.

7.4.5 Response of Vascular and Nonvascular Plants to Air Pollution

A. Nonvascular Species. The results of chlorophyll analyses and measurements of membrane leakage of *L. peltata* exposed to five different levels of SO_2 for two days is presented in table 7.4-13. As noted the chlorophyll a/b ratios of lichen thalli, both young and old, exposed to 4 ppm of SO_2 was significantly lower than for the lichen material in the control chambers. The results of the chlorophyll and a total chlorophyll analysis were either nonsignificant or inclusive. The differences for the young thalli were not as obvious as for the mature thalli. The chlorophyll a/b ratio at 2 ppm which was not different from the control. The ration for

Table 7.4-12. Density of seeded species at the section 6 interseeding study plots. Data taken in June and October, 1984. Totals followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

	Cover Annuals	Drill Seeded (density/linear m)		Broadcast Seeded (density/.5 m^2)	
		June	October	June	October
Fenced	High	7.0	0.2	0.2	0.0
	High	6.0	0.0	1.2	0.0
	Low	7.2	0.6	0.4	0.0
	Low	9.4	1.8	0.6	0.0
Unfenced	High	11.6	0.0	2.0	0.0
	High	4.4	0.2	0.2	0.0
	Low	11.8	0.2	2.6	0.0
	Low	9.8	0.0	0.2	0.0
Total		8.4^a	0.4^c	0.9^b	0.0^c

Table 7.4-13. Summary of results of various techniques used to measure the response of L. peltata a foliose lichen, to SO_2 fumigation for 2 days.

SO_2 Level	Total Chlorophyll mg/g		Chloro a mg/g		Chloro a/b mg/g		Membrane Leakage uhos/ml/g	
	Young	Mature	Young	Mature	Young	Mature	Young	Mature
0 ppm	7.22^{a}	13.78^{a}	1.37^{a}	2.24^{a}	34.40^{a}	37.82^{a}	1.59^{a}	0.05^{a}
.5 ppm	5.83^{a}	15.51^{a}	1.90^{a}	1.68^{a}	34.37^{a}	34.89^{a}	61.7^{b}	2.56^{ab}
1 ppm	4.49^{a}	13.63^{a}	1.66^{a}	1.96^{a}	34.50^{a}	34.57^{a}	4.20^{ab}	2.49^{ab}
2 ppm	4.32^{a}	13.49^{a}	1.23^{a}	1.63^{a}	31.49^{ab}	35.11^{a}	2.64^{a}	3.96^{b}
4 ppm	2.83^{a}	13.19^{a}	1.60^{a}	1.59^{a}	23.14^{b}	17.33^{b}	1.77^{a}	1.82^{ab}
Detectable level of SO_2 Sensitivity	Inconclusive	Inconclusive	Inconclusive	Inconclusive	Decrease at 4 ppm	Decrease at 4 ppm	Inconclusive	Inconclusive
F-value	$.908^{ns}$		1.950^{ns}		15.790**		4.702*	

** significant at $\alpha \leq .01$

* significant at $\alpha \leq .05$

ns Not statistically significant

the mature thalli decreased from 35.11 mg at 2 ppm to 17.cc mg/gm at 4 ppm, a statistically significant difference.

The membrane permeability technique of measuring damage to lichen tissue due to air pollution is a new technique and has not been fully tested as an acceptable method for measuring the sensitivity of lichens to air pollutants (Persons and Henriksson, 1981; Pearson and Rodgers, 1981). As noted in Table 7.4-13 membrane leakage as measured by electrical conductivity increased dramatically when lichen material was exposed to SO_2. However, due to the high variability the increased values were not significantly different from the control.

A correlation analysis was run between SO_2 levels and each of the four techniques to measure the condition of the lichen thalli (Table7.4-14). It was obvious in the correlation analysis that the chlorophyll a/b r io was the only technique that demonstrated differences between SO_2 level for mature lichen specimens, young lichen specimens and for the two li forms combined.

A regression analysis of chlorophyll a/b ratio and SO_2 levels is shown in Figure 7.4-1. The figure represents chlorophyll a/b ratios for mature lichen specimens only, since all other correlations were not significant.

From this experiment it was determined that the chlorophyll a/b ratio of mature lichen material was the best technique to measure or identify SO_2 sensitivity levels for L. peltata. The inconclusive results of the other techniques used to measure lichen tissue damage may be attributable to several conditions. It is known that the response of vascular plants and lichens to air pollutants is influenced by humidity (Treshow, 1984; Smith

Table 7.4-14. Correlation of chlorophyll a, total chlorophyll, chlorophyll a/b ratio and membrane leakage of young and mature lichen specimens with 5 levels of SO_2 fumigation.

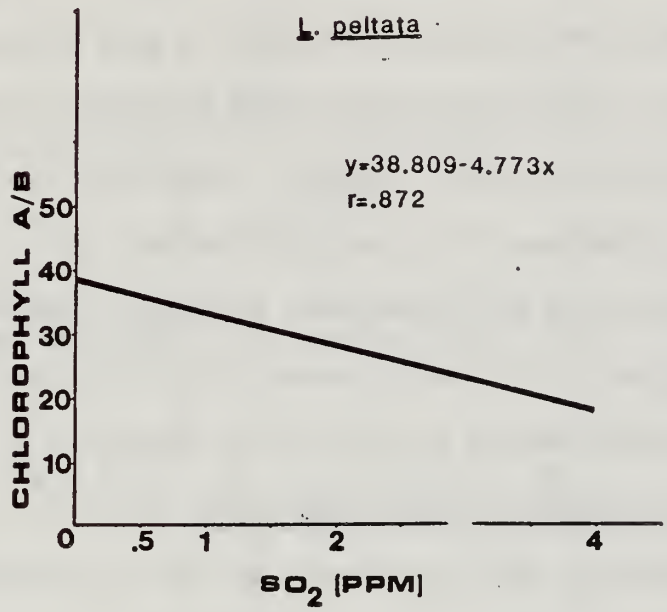
	Technique			
Life Form	Chloro a	Chloro a/b	Total Chloro	Mem. Perm.
Mature	$-.529^{ns}$	-.872**	$-.235^{ns}$	$-.290^{ns}$
Young	$-.374^{ns}$	-.834**	-.702**	$-.325^{ns}$
Mature and Young	$-.421^{ns}$	-.842**	$-.193^{ns}$	$-.086^{ns}$

* significant at $\alpha \leq .05$

** significant at $\alpha \leq .01$

ns Not statistically significant

Figure 7.4-1. Regression of chlorophyll a/b ratio of Lecanora peltata and SO_2 concentrations. Regression significant at $\alpha \leq .01$ level.



and Molesworth, 1973; Murdy and Ragsdale, 1980). The lichen thalli were kept in a container with a high humidity until the experiment was initiated. However, it was not possible to control or increase the humidity within the fumigation chambers so the lichen thalli quickly dried and in all probability reduced the effect of the SO_2. A more detailed experiment in which humidity was closely regulated would be needed to verify the actual levels of SO_2 sensitivity of L. peltata. From this experiment it was possible to see a decrease in chlorophyll content and an increase in electrical conductivity due to membrane leakage. These results suggest the use of L. peltata as an indicator species, but additional studies would be needed to confirm the levels at which it is sensitive to SO_2.

B. Vascular Species - 2 Day Experiment

Several different techniques were used to evaluate/measure the response of the four vascular plant species to SO_2 levels ranging from 0 ppm to 4 ppm during a 2-day fumigation period. Visual damage estimates were taken 5 days and 30 days after the fumigation period. Chlorophyll content was determined of leaf material collected at the same time the first visual evaluation was made, and selected transpiration readings were taken during day 1 of the 2 day experiment. A summary of the results of those analyses is presented in Table 7.4-15.

Of the four species tested sagebrush appears to be the most sensitive to the fumigation treatments used in this experiment. Based on the amount of chlorophyll a and total chlorophyll in the leaf material, sagebrush was found to be sensitive to SO_2 levels of 0.5 ppm. Other parameters measured, which included the chlorophyll a/b ratio, transpiration and percent visual

Table 7.4-15. Summary of response of 4 vascular plant species to 5 levels of SO_2 fumigations for 2 days. Values followed by common letters are not significantly different as tested by ANOVA and Fishers LSD mean separation tests ($F \leq .05$; $\alpha \leq .05$).

Species	SO_2 level (ppm)	% Visual Damage		Chlorophyll Analysis				Transpiration
				Chlorophyll a		Chlorophyll a/b Ratio	Total Chlorophyll mg/g	$mg \cdot cm^{-2} s^{-1}$
		After 2 days	After 30 days	Dry Wt. mg/g	Wet Wt. mg/g			
Sagebrush	0	0^a	19.6^a	9.0^a	4.8^a	35.8^{ab}	19.3^a	3.83^a
	.5	$.9^a$	24.6^a	6.1^b	3.7^b	36.5^a	14.0^b	2.90^{ab}
	1	7.5^a	26.4^a	4.7^b	2.7^b	32.6^b	9.6^c	2.97^{ab}
	2	24.4^b	43.2^b	4.2	2.7^b	27.7^c	10.8^{bc}	2.16^{bc}
	4	63.6^c	56.4^c	2.3^c	1.6^c	25.5^c	5.2^d	1.19^c
Detectable level of SO_2 Sensitivity		2 ppm	2 ppm	.5 ppm	.5 ppm	2 ppm	.5 ppm	2 ppm
Rabbitbrush	0	0^a	13.8^a	16.5^a	6.7^a	37.5^a	16.1^a	9.15^a
	.5	$.1^a$	19.9^{ab}	17.5^a	6.8^a	38.4^a	18.2^a	--
	1	3.2^a	26.4^b	16.6^a	6.5^{ab}	36.1^a	16.6^a	--
	2	17.9^b	35.7^c	13.6^b	5.6^{bc}	31.4^b	14.8^a	--
	4	93.9^c	64.6^d	5.6^c	4.6^c	21.2^c	10.4^b	4.32^b
Detectable level of SO_2 Sensitivity		2 ppm	1 ppm	2 ppm	2 ppm	2 ppm	4 ppm	N/A

Table 7.4-15. (Continued)

Species	SO_2 level (ppm)	% Visual Damage		Chlorophyll Analysis				Transpiration
				Chlorophyll a		Chlorophyll a/b	Total Chlorophyll	mg $cm^{-2}s^{-1}$
		After 2 days	After 30 days	Dry Wt. mg/g	Wet Wt. mg/g	Ratio	mg/g	
Utah Juniper	0	0^a	1.6^a	11.5^a	6.3^a	34.2^a	18.0^a	3.97^a
	.5	0^a	1.1^a	11.7^a	5.9^{ab}	31.9^{ab}	17.1^{abc}	
	1	0^a	1.6^a	13.8^a	6.6^a	33.1^a	20.9^a	
	2	17.3^b	13.8^b	9.5^b	4.9^b	28.8^{bc}	15.9^{bc}	
	4	80.0^c	64.6^c	6.6^c	3.3^c	25.9^c	13.5^c	1.50^b
Detectable level of SO_2 Sensitivity		2 ppm	2 ppm	2 ppm	2 ppm	2 ppm	2 ppm	N/A
Fourwing Saltbush	0	0^a	12.4^a	4.4^a	2.1^a	44.7^a	9.0^a	2.86^a
	.5	0^a	16.1^a	4.7^a	2.2^a	46.1^a	10.0^a	2.44^a
	1	0^a	17.5^a	5.4^a	2.4^a	47.3^a	10.6^a	2.66^a
	2	0^a	17.4^a	4.1^a	2.0^a	44.6^a	7.9^a	2.42^a
	4	0^a	19.3^a	3.9^a	1.8^a	44.5^a	7.4^a	1.95^a
Detectable level of SO_2 Sensitivity		N/S	N/S	N/S	N/S	N/S	N/S	N/S

damage, indicated sensitivity at 2 ppm of SO_2.

The amount of chlorophyll a present on a wet weight basis in the leaf material of sagebrush decreased from 4.8 mg/g in the control chambers to 3.7, 2.7 and 2.7 mg/g in fumigation chambers receiving 0.5, 1 and 2 ppm, respectively of SO_2. All three chambers were significantly different from the control. At 4 ppm of SO_2 the amount of chlorophyll decreased to 1.6 mg/g, significantly lower than all other chambers. Similar trends were observed with chlorophyll a on a dry weight basis and with total chlorophyll.

Transpiration measurements were not as sensitive as the chlorophyll analyses. Transpiration measurements in chambers receiving 0 ppm, 0.5 ppm and 1 ppm were not significantly different. Transpiration in the chambers rec ıving 2 ppm did show values significantly lower than that in the control cha ›ers (2.16 ug/cm^2/S). Transpiration values in chambers receiving 4 ppm of O_2 were significantly lower than in chambers receiving 0 ppm, .5 ppm and 1 p ı, but not significantly different from the chamber receiving 2 ppm of SO_2.

Visual damage estimates were made three days after the 48 hour exposure period. During the three day waiting period the plants remained in the chambers in which air continued to be circulated and filtered to avoid a buildup of temperature and ambient air pollution. This short waiting period allowed time for the symptoms of SO_2 damage to become visually noticeable. During the experiment no visual damage was observed on the different plant species. However, 2-3 days after SO_2 injection into the chambers had stopped leaf curling and discoloration became evident. As explained in the

methodology section (7.3.3) all dead leaves and plant material were removed from each plant prior to being placed in the fumigation chambers. This allowed an accurate assessment of SO_2 damage after the fumigation period. Visual estimates of SO_2 damage were less than 1% in the chambers receiving .5 ppm and 7.5% in the chambers receiving 1 ppm both, of which are not significantly different from the control. Nearly 25% damage was observed on plants receiving 2 ppm of SO_2 and 63.6% damage on plants in the chamber receiving 4 ppm. Both were significantly higher than the control.

A correlation of SO_2 levels with the values obtained from each of the different chlorophyll analyses used to measure the response of sagebrush to SO_2 fumigation was run. It was determined from the correlation that for sagebrush the chlorophyll a/b ration had the highest correlation coefficient (Table 7.4-16). Although the chlorophyll a/b ratio was the higher correlated of the four techniques tested all four had P values of less than .001.

From this experiment it was shown that the response of sagebrush to relatively low levels of SO_2 fumigation can be measured using several techniques, including a visual analysis. Its use in the vegetation monitoring program is justified from this experiment and should be a valuable monitoring species after plant startup.

Rabbitbrush, the second of four vascular species to be tested, was found to be sensitive to approximately 2 ppm of SO_2. This observation is based on the different chlorophyll analyses, visual damage estimates and transpiration measurements, all of which indicate a detectable sensitivity level of 2 ppm of SO_2. The chlorophyll content of the plant material in the chambers receiving 2 ppm (5.6 mg/g) was found to be significantly different

Table 7.4-16. Correlation of SO_2 levels with 4 chlorophyll measurements of plant leaf material used to assess the condition of 4 native plant species. 2 Day Experiment.

Species		Chlorophyll a Dry Wt.	Chlorophyll a Wet Wt.	Chlorophyll a/b Ratio	Total Chlorophyll
Sagebrush	Coefficient	-.6837	-.6380	-.7990	-.5921
	P-Value	.000	.000	.000	.000
Rabbitbrush	Coefficient	-.6948	-.4710	-.8360	-.5481
	P-Value	.000	.000	.000	.000
Utah Juniper	Coefficient	-.6001	-.6700	-.6450	-.4512
	P-Value	.000	.000	.000	.000
Fourwing Saltbush	Coefficient	-.2096	-.2260	-.0810	-.2587
	P-Value	.41	.072	.346	.015
All Species	Coefficient	-.3912	-.3490	-.4120	-.4103
	P-Value	.000	.000	.000	.000

from that of the control (6.7 mg/g). Chlorophyll content decreased to 4.6 mg/g in chambers containing 4 ppm of SO_2.

Similar trends and levels of sensitivity were observed with the results of the other chlorophyll analyses and visual evaluations of plant damage. The only exceptions were with total chlorophyll and visual damage estimations after 30 days. The only difference in total chlorophyll was in the chambers receiving 4 ppm of SO_2. All other chambers receiving SO_2 were not significantly different from the control. Visual damage estimates after 30 days indicated a significant increase in the percentage damage of the plant material that had been in chambers with 1 ppm of SO_2.

Transpiration measurements were only taken in control chambers and chambers with 4 ppm SO_2, therefore an analysis of rabbitbrush based on transpiration is not possible. The only observation is the transpiration in rabbitbrush decreased from 9.15 ug/cm^2/S in the control to 4.32 ug/cm^2/S in chambers with 4 ppm of SO_2.

A correlation was again run to determine which of the four chlorophyll analyses was best correlated with the five SO_2 levels (Table 7.4-16). For rabbitbrush it was found that the chlorophyll a/b ratio was the technique most highly correlated with SO_2 levels. As was the case for sagebrush, all chlorophyll analysis techniques correlated with SO_2 levels had P values of less than .001.

From this experiment it was determined that rabbitbrush was sensitive to approximately 2 ppm of SO_2 when exposed for a 48 hour period. It was also determined that like sagebrush, the determination of the chlorophyll a/b ratio is a good technique to measure the response of rabbitbrush to increased levels of SO_2.

The response of Utah juniper to the various treatments of SO_2 is very similar to that of rabbitbrush. Although chlorophyll values and visual damage estimates differ slightly, the overall trend and level of detectable sensitivity are the same. Regardless of the technique used it was found that Utah juniper showed visual damage and decreases in chlorophyll content in chambers injected with 2 ppm of SO_2. Values obtained for both visual damage and chlorophyll content from the chambers receiving .5 ppm and 1 ppm were not significantly different from the control. Transpiration was only determined on plant material in the control chambers and the chambers with 4 ppm of SO_2. The reduction in transpiration from 3.97 $ug/cm^2/S$ to 1.50 $ug/cm^2/S$ was statistically significant at the 0.01 level.

The Utah juniper plants used in this experiment were gallon container stock and therefore represent young plant material. This fact is not critical for the other species used in this experiment, since the plants of rabbitbrush, sagebrush and fourwing saltbrush are fairly representative of the plant material on the tracts. However, in the case of Utah juniper, most of the plants on site are mature individuals which may not respond as the young plants used in this experiment. It was noted during the course of the fumigation period that it was the young buds and new leaf shoots that were browning on the Utah juniper plants, and therefore a similar effect may be expected on the juniper plants on the tracts although they may be more mature.

Results on the sensitivity of fourwing saltbush to the different levels of SO_2 fumigation was somewhat unexpected (Table 7.4-15). No level of sensitivity of fourwing saltbush was detectable under the current experimental design. The results of several studies conducted by Dr. G. Ray

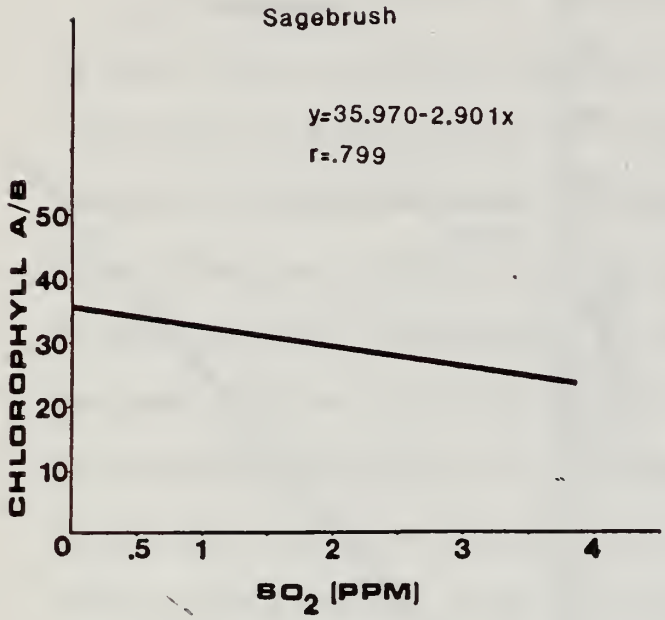
Thompson at the Statewide Air Pollution Research Center at the University of California, Riverside, on fourwing saltbush has shown similar results. Even after months if exposure to SO_2 fourwing saltbush has not shown any measurable signs of reduced plant metabolism or leaf damage.

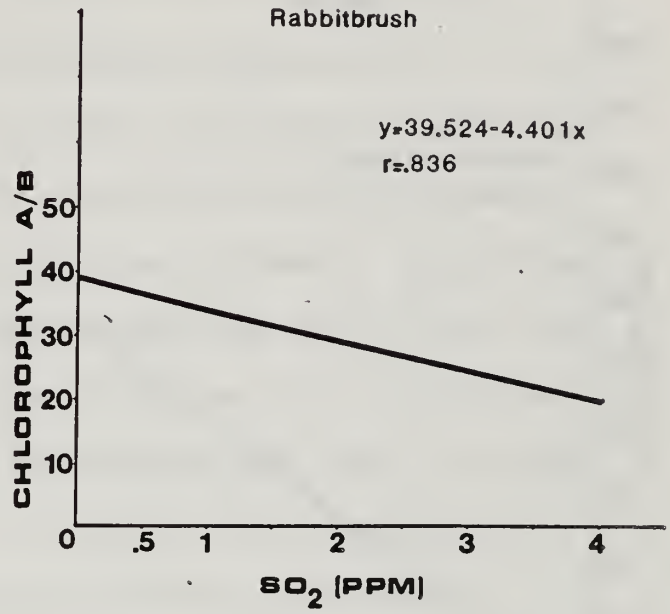
An evaluation of the techniques used to measure the response of each of the vascular plant species to the different levels of SO_2 fumigation has been alluded to during the discussion on each of the plant species. It was found that the chlorophyll a/b ration was a good indicator of the plant condition as it may be affected by fumigation with SO_2 (Table 7.4-16). To summarize the findings of the 2-day experiment a regression analysis was run between SO_2 levels and chlorphyll a/b ratio for sagebrush, rabbitbrush and Utah juniper. Fourwing saltbush was not included because no statistical differences were determined between SO_2 treatment levels.

Figures 7.4-2 and 7.4-3 show the results of the regression analysis for the three vascular plant species used in the experiment. All three species show a gradual decline in the chlorophyll a/b ratio and an increase in visual damage with increased amounts of SO_2. Probably the sharpest decline in the chlorophyll a/b ratio was with rabbitbrush which dropped from near 40 in control chambers to about 22 in chambers containing 4 ppm of SO_2. The same was true for visual damage estimates for rabbitbrush which is at 0 in the control chambers but increases to about 80% at 4 ppm SO_2.

The results of the two day experiment have confirmed the use of sagebrush as a key monitoring species on the oil shale tracts Ua and Ub. Although rabbitbrush shows marked responses to SO_2, its use in a monitoring program such as the one designed for the White River Shale Project is limited because of the impact local rodent populations have on this species

Figure 7.4-2. Regression of chlorophyll a/b ratio and SO_2 concentrations for sagebrush, rabbitbrush and Utah juniper. All regressions significant at $\alpha \leq .01$ level.





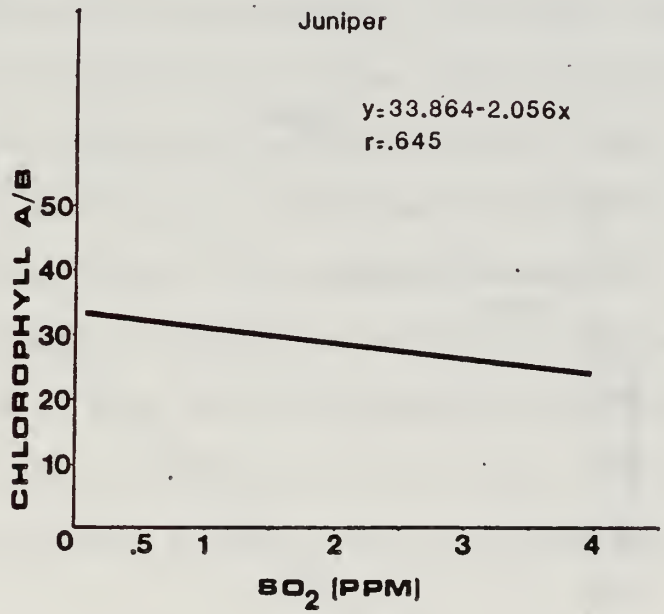
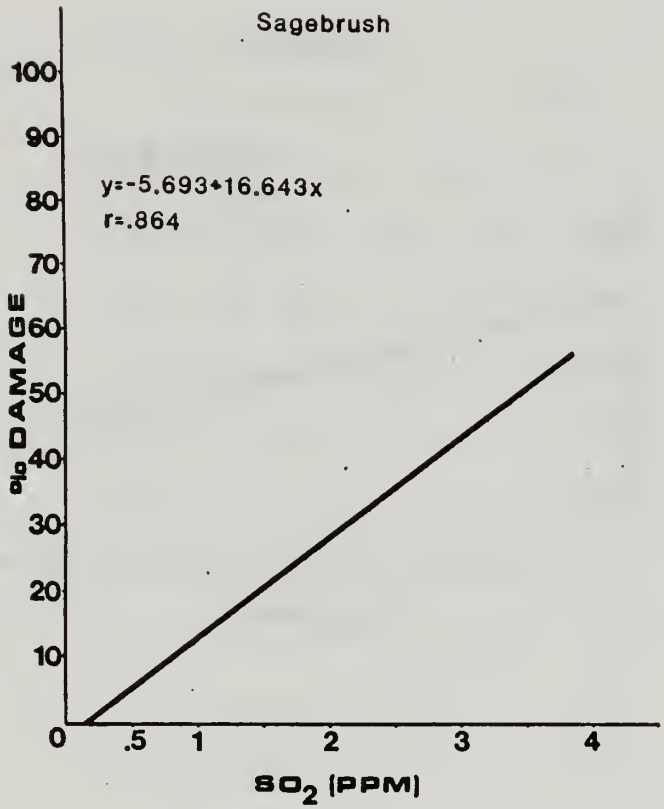
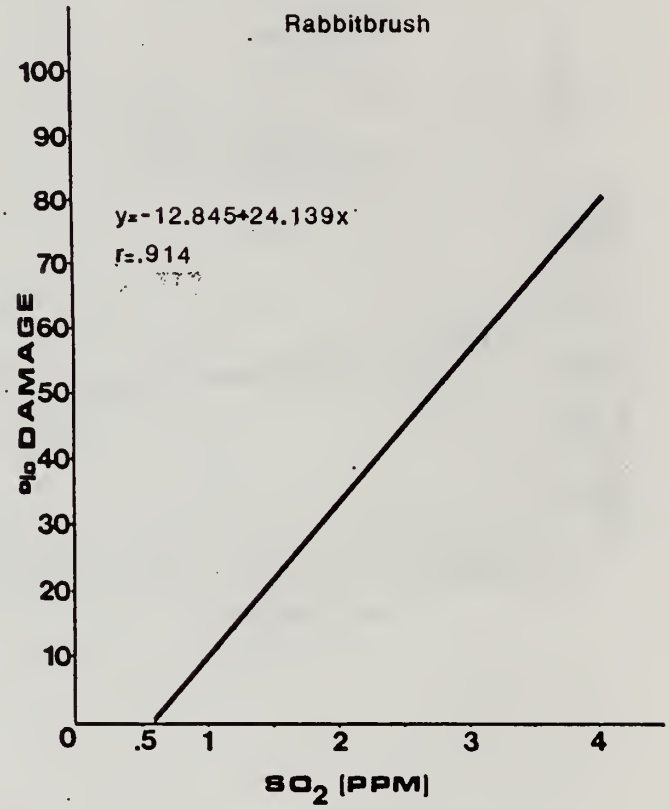
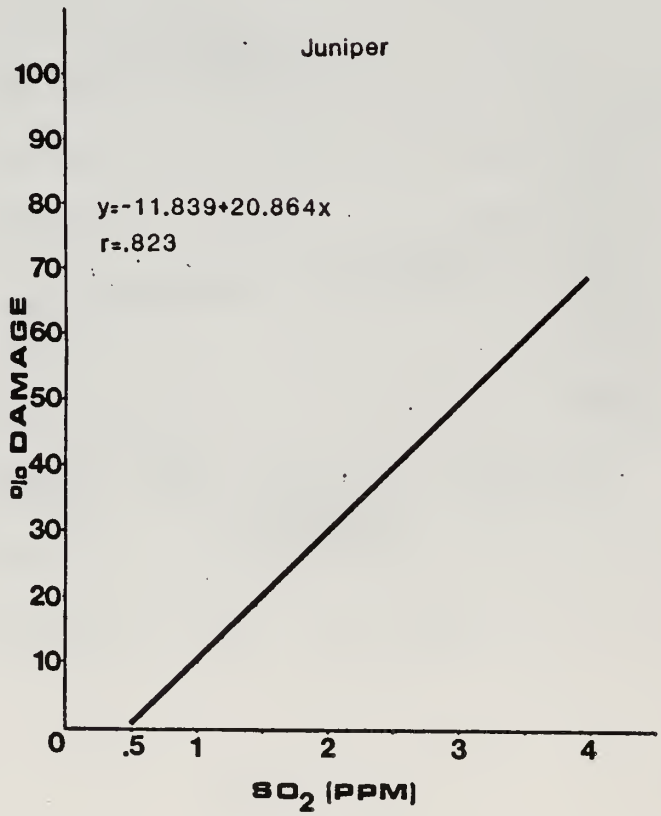


Figure 7.4-3. Regression of % visual damage and concentration of SO_2 for sagebrush, rabbitbrush and Utah juniper. All regressions significant at the $\alpha \leq .01$ level.







and also due to its limited distribution on tract in comparison to sagebrush.

C. Vascular Species - 30 Day Experiment

The SO_2 levels used for the 30 day experiment were .1 ppm, .2 ppm, .4 ppm, .8 ppm and 0 ppm (control). The methodology employed was essentially that used during the 2 day experiment. Chlorophyll analysis was conducted as during the 2 day experiment, as was transpiration and the visual damage evaluation at the termination of the experiment. In addition to those analyses a measurement of net photosynthesis was made 15 days after the experiment was initiated and again after 30 days or at the termination of the fumigation period. Transpiration measurements were taken at the same time as were those for photosynthesis. The results of the analyses are given in Table 7.4-17. Fourwing saltbush was not used in the 30 day experiment because of its insensitivity to SO_2 determined during the 2 day experiment and from the results of other studies.

Based on the various measurments of SO_2 damage, sagebrush was found to be sensitive to SO_2 levels of .4 ppm. The chlorophyll a (mg/g wet weight of plant material) content of sagebrush decreased from 3.73 mg/g in the control chambers to 2.61 mg/g in the chambers receiving .4 ppm of SO_2 was not significantly different from the control chambers. The chlorophyll a content of sagebrush in the chambers receiving .8 ppm was not different from the chambers with .4 ppm. The same trend also existed for the chlorophyll a/b ratio except the plant chlorophyll a/b ratios in the chambers with .8 ppm were significantly different from the chambers receiving .4 ppm of SO_2.

Visual damage estimates followed a very similar trend. No visual damage was observed in chambers receiving 0 ppm, .1 ppm, and .2 ppm of SO_2.

Table 7.4-17. Summary of response of 3 vascular plant species to 5 levels of SO_2 fumigation for 30 days. Values followed by common letters are not significantly different as tested by ANOVA and Fishers LSD mean separation tests ($F \leq .05$; $\alpha \leq .05$).

Species	SO_2 level (ppm)	% Visual Damage	Chlorophyll Analysis: Chlorophyll a Wet wt. mg/g	Chlorophyll a Dry wt. mg/g	Chlorophyll a/b Ratio	Total Chlorophyll mg/g	Transpiration $mg/cm^2/s$ After 15 Days	Transpiration After 30 Days	Net Photosynthesis $mol/m^2/s$ After 15 Days	Net Photosynthesis After 30 Days
Sagebrush	0	0^a	3.73^a	7.51^{ab}	37.61^a	10.11^{ab}	1.62^a	1.50^a	4.66^a	2.76^a
	.1	0^a	3.73^a	8.00^a	39.40^a	11.52^a	2.36^a	$.97^b$	2.80^b	2.52^a
	.2	$.4^a$	3.86^a	8.15^a	35.85^a	11.95^a	2.07^a	$.64^{bc}$	2.90^b	2.98^a
	.4	34^b	2.61^b	5.17^b	31.03^b	7.62^{bc}	1.94^a	1.01^b	2.14^{bc}	1.78^a
	.8	73^c	2.29^b	2.48^c	25.57^c	4.33^c	1.33^a	$.49^c$	$.86^c$	1.17^a
Detectable level of SO_2 Sensitivity		.4 ppm	.4 ppm	.8 ppm	.4 ppm	.8 ppm		.1 ppm	.1 ppm	
Rabbitbrush	0	0^a	5.79^{ab}	12.58^b	39.08^a	16.07^a	6.66^a	3.40^a	4.83^a	2.69^a
	.1	$.5^a$	6.71^a	15.60^a	39.20^a	16.72^a	7.00^a	1.72^a	4.91^a	2.60^a
	.2	1.0^a	4.94^b	10.99^{bc}	38.50^a	11.34^b	8.72^a	1.50^{bc}	3.60^a	2.92^a
	.4	15.0^a	3.29^c	8.47^c	32.87^b	9.37^b	4.74^a	2.15^b	3.80^a	1.81^a
	.8	72.0^b	1.67^d	3.47^d	21.76^c	4.79^c	6.00^a	1.18^c	2.10^a	3.80^a
Detectable level of SO_2 Sensitivity		.8 ppm	.2 ppm	.4 ppm	.4 ppm	.2 ppm	--	.1 ppm	----	N/S
Utah Juniper	0	0^a	5.97^a	11.52^a	34.23^a	16.01^a	1.97^a	1.43^a	5.12^a	4.60^a
	.1	$.3^a$	5.45^{ab}	10.79^{ab}	34.20^a	15.27^{ab}	2.00^a	$.54^b$	4.15^{ab}	4.30^a
	.2	1^a	5.30^{ab}	10.40^{ab}	32.78^a	12.95^{abc}	1.49^b	$.78^b$	3.12^{bc}	3.39^a
	.4	5^b	4.71^{bc}	9.67^{ab}	28.43^b	11.35^c	1.48^b	$.77^b$	2.41^{cd}	1.78^b
	.8	9^c	3.99^c	8.63^b	31.37^{ab}	12.20^{bc}	$.99^c$	$.48^b$	1.48^d	1.88^b
Detectable level of SO_2 Sensitivity		.4 ppm	.4 ppm	.8 ppm	--	.4 ppm	.2 ppm	.1 ppm	.2 ppm	.4 ppm

The 34% visual damage in chambers receiving .4 ppm was significantly different from the 73% estimated in chambers with .8 ppm of SO_2.

Chlorophyll a (mg/g dry weight of plant material) and total chlorophyll content of sagebrush was only significantly reduced in chambers receiving .8 ppm of SO_2. Although chambers receiving .4 ppm were different from those receiving .1 and .2 ppm, they were not significantly different from the control chambers.

Transpiration measurements of sagebrush leaf material in chambers with .1 ppm were found to be lower than measurements taken in the control chambers. This difference was observed at the termination of the fumigation period, but not at the 15-day mark of the experiment. Just the opposite was the case for net photosynthesis measurements. Photosynthesis measurements taken 15 days after the initiation of the experiment in chamber with .1 ppm were significantly lower than the control chamber. At the end of the fumigation period when net photosynthesis measurements were taken there were no differences between chambers. Chambers with .8 ppm did show lower rates of transpiration and photosynthesis than found in chambers receiving .1 ppm, .2ppm, and .4 ppm.

Rabbitbrush was probably the most sensitive species of the three tested for long term effects of exposure to SO_2. The total chlorophyll and chlorophyll a (mg/g wet weight plant material) for rabbitbrush leaf material were both lower in chambers with .2 ppm of SO_2 than in the control chambers. The chlorophyll a/b ratio and chlorophyll a (mg/g dry weight of plant material) of rabbitbrush placed in chambers with .4 ppm of SO_2 were significantly lower than the control plants. Leaf material in chambers receiving lower concentrations of SO_2 were not significantly different from

the control. The visual damage of rabbitbrush due to SO_2 was not as obvious under the lower concentration levels. Only those rabbitbrush plants in chambers with .8 ppm showed visual signs of SO_2 damage.

There was no reduction in net photosynthesis for rabbitbrush due to exposure to SO_2, at either the 15 day measurement or the 30 day measurement. There were no differences in transpiration rates during the 15 day sampling time, but transpiration rates of rabbitbrush measured at the end of the experiment were lower in chambers with .1 ppm of SO_2 than in the control. Chambers receiving .2 and .4 ppm of SO_2 had similar transpiration values as the chambers with .1 ppm, however transpiration rates in chambers with .8 ppm of SO_2 were significantly lower than those found in all other chambers.

Utah juniper sensitivity to SO_2 was found to be similar to that of sagebrush. The chlorophyll a (mg/g wet weight content of Utah juniper decreased form 5.97 mg/g in the control chamber to 4.71 mg/g in chambers receiving .4 ppm of SO_2. Chambers with .1 and .2 ppm of SO_2 were the same as the control and the chamber with .8 ppm was not different from the chamber with .4 ppm of SO_2. Based on dry weight values only the chlorophyll a content of rabbitbrush in chambers with .8 ppm were significantly different from the control.

The total chlorophyll content of rabbitbrush in chambers with .4 ppm of SO_2 was found to be statistically different from the control However, the chlorophyll values for these chambers were not different from those determined for plant material in chambers with .8 ppm or .2 ppm of SO_2. The chambers with .2 ppm were not significantly different from the control chambers.

Visual damage to juniper was minimal during the 30 day experiment. Only 5% damage was observed in chambers receiving .4 ppm of SO_2, which was significantly different from the control as well as chambers receiving .1 and .2 ppm. The 9% damage estimated in chambers receiving .8 ppm was significantly lower than all other chambers.

Net photosynthesis values for juniper taken 15 days after the experiment started in chambers receiving .2 ppm were lower than those in the control chambers. By the end of the experiment only the net photosynthesis estimates in chambers with .4 ppm of SO_2 were significantly lower than in the control chambers.

Fifteen days after initiation of the experiment, transpiration rates for juniper placed in chambers receiving .2 ppm of SO_2 were found to be significantly lower than those in the control chambers. By the end of the fumigation period transpiration values were found to be significantly lower in chambers with only .1 ppm of SO_2.

Based on chlorophyll a/b ratios and chlorophyll a (wet weight) content (Table 7.4-18) and after an exposure period of 30 days, sagebrush and Utah juniper leaf material was found to be sensitive to as low as .4 ppm of SO_2. Rabbitbrush was equally sensitive, showing some sensitivity to SO_2 levels of .2 ppm. Transpiration rates in all three species decreased at an SO_2 level of .1 ppm.

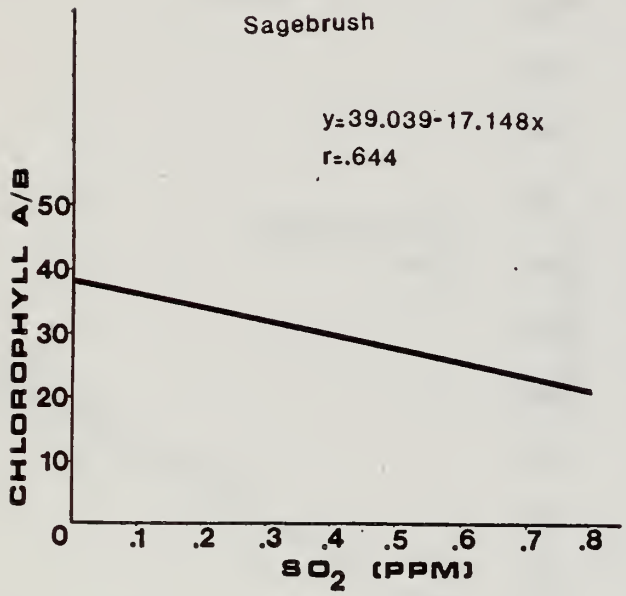
Figures 7.4-4 and 7.4-5 show the results of a regression analysis for the three vascular plant species used in the experiment. All three species show a decline in the chlorophyll a/b ratio and an increase in visual damage with increased amounts of SO_2. All three species show a similar rate of decline in the chlorophyll a/b ratio. Visual damage estimates increased

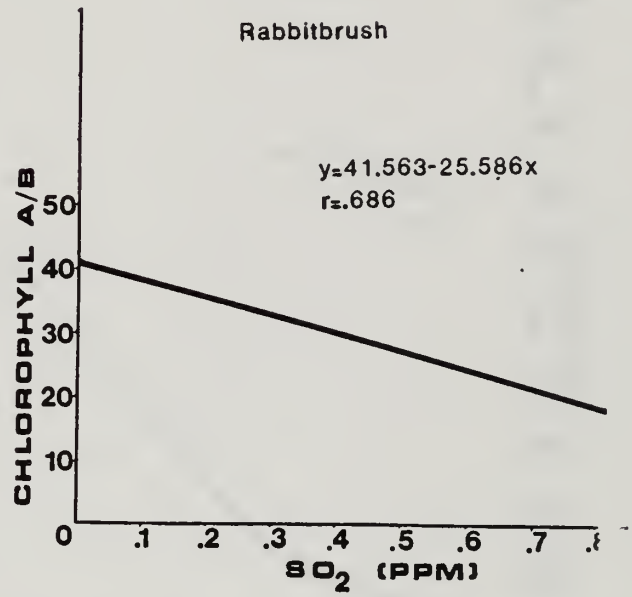
Table 7.4-18.

Correlation of SO_2 levels with 4 chlorophyll measurements of condition of 3 native plant species other exposrue to SO_2 for 30 days.

Species		Chlorophyll a Dry Wt.	Chlorophyll a Wet Wt.	Chlorophyll a/b Ratio	Total Chlorophyll
Sagebrush	Coefficient	.6423	.398	.6440*	.5032
	P-Value	.000	.000	.000	.000
Rabbitbrush	Coefficient	.6095	.7330*	.6860	-.6223
	P-Value	.000	.000	.000	.000
Utah Juniper	Coefficient	.3719	-.5370*	.3590	-.3575
	P-Value	.000	.000	.000	.001
Total	Coefficient	-.4828	-.5180	-.5710*	-.4787
	P-Value	.000	.000	.000	.000

Figure 7.4-4. Regression of chlorophyll a/b ratio and SO_2 concentrations for sagebrush, rabbitbrush and Utah juniper. All regressions significant at $\alpha \leq .01$ level.





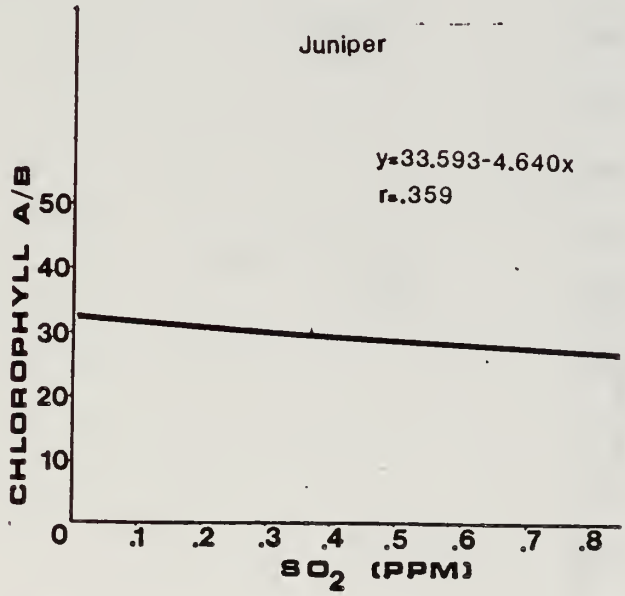
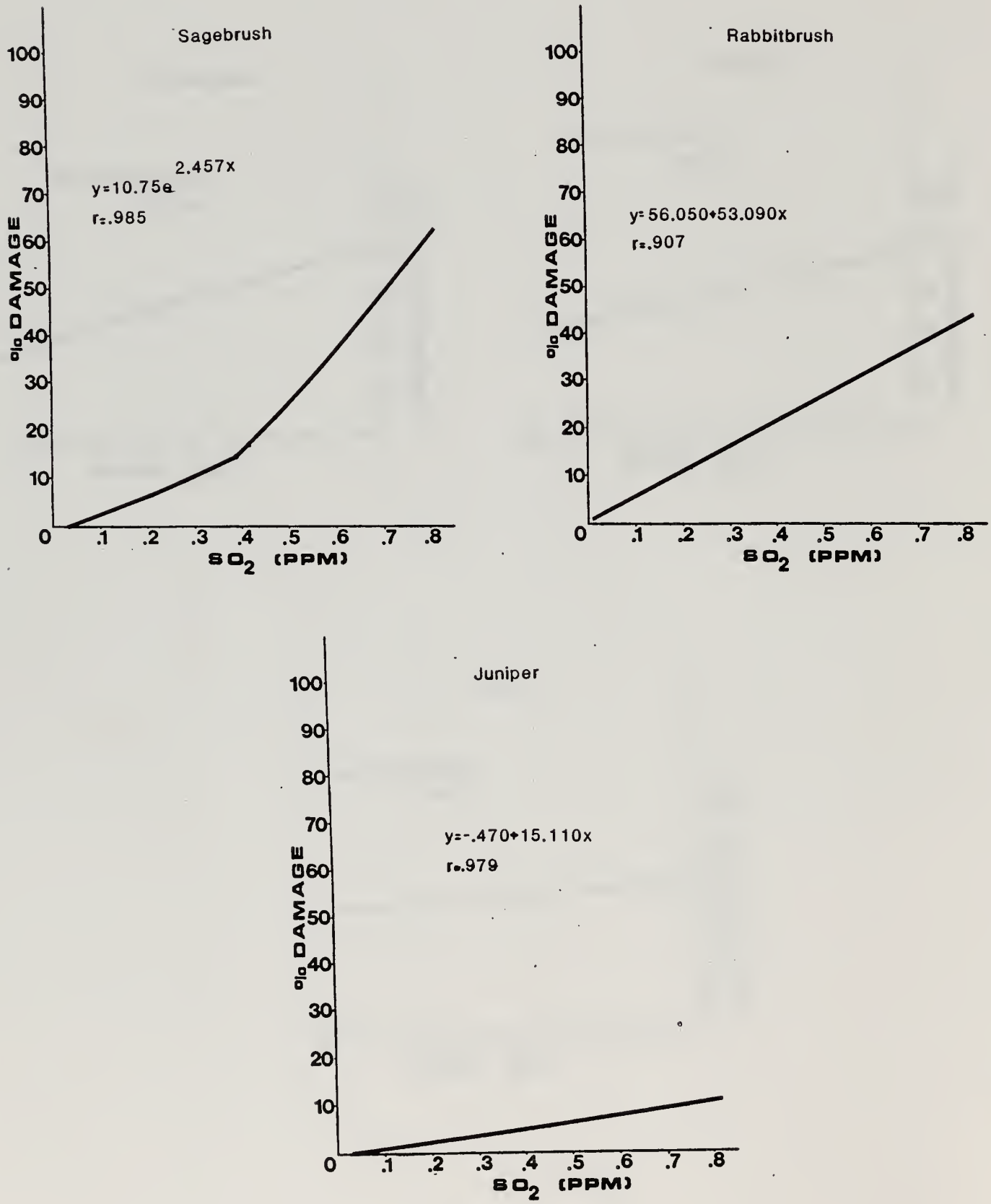


Figure 7.4-5. Regression of % visual damage and concentration (ppm) of SO_2 for sagebrush, rabbitbrush and Utah juniper. All regressions significant at $\alpha \leq .01$ level.



markedly for sagebrush and rabbitbrush as SO_2 levels increased. However, estimates for Utah juniper were much more gradual and even at .8 ppm of SO_2 only slightly over 10% visual damage is expected.

The results of the 30 day experiment are very similar to the results of the two day experiment. Sagebrush, rabbitbrush and Utah juniper were found to be sensitive to SO_2 fumigation, and when exposed for 30 days all three species showed sensitivity at SO_2 levels as low as .2 ppm, but this was most noticeable at .4 ppm. The .4 ppm level is approximately three times higher than the allowable 24 hr standard (NAAQS) of .14 ppm which the commercial facility would operate at under normal conditions. It was also determined that the chlorophyll a/b ratio and chlorophyll a (wet weight) were the two measurements of SO_2 damage highly correlated with SO_2 treatment levels (Table 7.4-18). These results coincide with those of the 2-day experiments.

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markedly for sagebrush and rabbitbrush as SO_2 levels increased. However, estimates for Utah juniper were much more gradual and even at .8 ppm of SO_2 only slightly over 10% visual damage is expected.

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8.0 ECOSYSTEM ANALYSIS

8.0 ECOSYSTEM ANALYSIS

8.1 INTRODUCTION

The White River Shale Oil Corporation (WRSOC) in its environmental monitoring program is mandated to fulfill the guidelines outlined by the Oil Shale Project Office (OSPO). Publication of an Environmental Monitoring Manual (EMM) in 1982 established the framework for meeting these OSPO guidelines. Within this document, WRSOC established overall program goals as well as goals for each of the five major environmental disciplines; air resources, vegetation, aquatic biology, terrestrial fauna and water resources. WRSOC recognized the need for integrating the information generated within these five disciplines and maintaining focus for achieving the OSPO guidelines. It was also recognized that the program must be flexible, allowing change and refinement as knowledge about the tract ecosystem and potential impacts grows. Ecosystem Analysis was the mechanism chosen to accomplish this task.

Ecosystem Analysis, which was initiated in 1983, is conducted under the direction of Ecosystem Research Institute (ERI) of Logan, Utah. In 1984, Ecosystem Analysis continued work initiated in 1983, and focused on redirection of the entire White River Shale Project (WRSP) environmental program to reflect planned reduction of development efforts. Completion of the data library and data management system was given high priority. A summary of 1984 accomplishments follows.

8.2 SUMMARY

This summary describes the major tasks addressed by Ecosystem Analysis in 1984. These tasks include: centralization of all environmental data under a uniform library and cataloguing system; completion of a documented data management system; development of computer software to promote efficient data acquisition and analysis; evaluation of important ecological relationships within and among environmental disciplines; and pathway identification. Recommendations for program improvement are also included.

8.2.1 Assemblage of WRSP 1984 Environmental Data

Environmental data collected in the five disciplines in 1983 were placed on computer tapes and sent to WRSOC and OSPO by each consultant during 1984. The tapes sent to WRSOC were then sent to ERI for inclusion in the data management system. These tapes were all received by the end of June of 1984.

8.2.2 Development and Maintenance of a Data Library and Cataloguing System for WRSP Environmental Data

A data library and cataloguing system was formalized and implemented during 1984. This system was set up to be maintained by ERI at its facilities in Logan, Utah. It was designed to provide ready access to the environmental data base for analysis or data transfer. Procedures for cataloguing and storing the data in the library were developed.

The cataloguing system developed includes procedures for logging in and cataloguing data tapes and associated documentation when received. For all data, this system contains information on the type of data was collected, initial and final sampling dates for each data type, frequency of data

collection, location of sample site, consultant responsible for data collection and the name of the data file in which each data type may be found. All data files for 1974 through 1983 for air resources, aquatic biology, terrestrial fauna, vegetation and water resources have been catalogued and stored in the library. Two computer tapes containing this environmental data were submitted to WRSOC in December of 1984 for storage at their facilities in Vernal, Utah.

8.2.3 Development of Computer Software for Data Acquisition and Analysis

Four computer programs were activated or developed to be used in conjunction with the data library. Two of the programs are used to copy data files from tape to the VAX computer system at Utah State University (USU) and from the computer to tape. A third program, LIBRARY, is used to determine the availability, location in the data base, sampling frequency, sample locations and dates of collection for specified parameters. MONITOR, developed under previous WRSOC contract, was reactivated in 1983 to provide a method for identifying changes in the relationships of specific parameters used to monitor oil shale development.

8.2.4 Evaluation of Important Ecological Relationships

An evaluation of important ecological relationships that might be useful in monitoring potential environmental impacts associated with oil shale development was initiated in 1983. An evaluation of the relationship between meteorological and vegetation data for usefulness in the WRSP was initiated in 1983 and completed in early 1984. Results, discussion and

recommendations emerging from this analysis are included in the 1983 Annual Report for Ecosystem Analysis (ERI, 1984).

The results of this effort, combined with a redirection in WRSOC's development schedule, caused a change in the evaluation of ecological relationships during 1984. Two documents were produced and submitted to WRSOC entitled "WRSP Environmental Monitoring Program Considerations' and "Guidelines for WRSP environmental Monitoring Program Redirection'. These "in-house" papers were designed to aid WRSOC in developing a logical environmental program during its proposed period of reduced activity and to help focus this program toward better impact detection when development resumes.

8.2.5 Pathway Identification

Pathway identification refers to the pathway of movement of pollutants or perturbations through the environment. Due to the reduction in development effort by WRSOC, the role of pathway identification was changed during 1984. Pathway identification was originally proposed as a method of redirecting full-scale monitoring efforts to focus on parameters known to be sensitive to expected impacts of development. During 1984, pathway identification was used as a means of reducing the monitoring efforts to a minimum level. Selection of parameters to be monitored during the next years of project inactivity as based on the sensitivity of parameters to expected impacts of development. In coordinating the development of the interim environmental program, ERI has stressed the importance of pathway identification to the interim monitoring program as well as to future programs to be initiated

when development resumes. These efforts are described in the two documents prepared for WRSOC mentioned in the previous section.

8.2.6 Recommendations For Program Improvement

The following are recommendations for the environmental monitoring program that have come out of the Ecosystem Analysis program:

1. Work toward a single, integrated environmental monitoring program should continue;

2. Monitoring efforts should be directed toward detecting impacts and away from baseline description; and

3. Work should continue to develop a set of parameters for monitoring in each discipline that are sensitive to the potential impacts of oil shale development.

8.3 PROGRAM DESCRIPTION

8.3.1 Introduction

The Ecosystem Analysis progra was created to provide a mechanism for integrating environmental data from the different environmental monitoring disciplines and providing recommendations to WRSOC for refinements to the environmental monitoring program. During 1983 and 1984, most of the goals of Ecosystem Analysis have been accomplished.

8.3.2. Objectives

The objectives of the Ecosystem Analysis program included four major long-term goals with several related tasks. The major goals were:

1. Centralize all environmental data from all disciplines under a uniform library and cataloguing system;

2. Develop efficient computer software to perform inter- and intra-disciplinary data analysis;

3. Develop a complete, documented system which may be operated by WRSOC personnel at a future date; and

4. Perform evaluation of existing and potential ecosystem relationships.

The tasks outlined in 1984 to address these objectives were:

1. Coordinate with WRSOC to obtain 1983 environmental data;

2. Catalogue, document and maintain all WRSP environmental data files under a single system;

3. Develop and update computer software to promote efficient data acquisition and analysis;

4. Analyze important relationships within and among the environmental disciplines;

5. Identify the important pollutants associated with oil shale development and the pathways by which those pollutants exert an effect on the ecosystem; and

6. Provide recommendations to WRSOC concerning changes in sampling methodology which would reduce the variability and increase the sensitivity of important parameters and relationships.

All of these tasks were addressed during 1984 with the completion of tasks 1 through 3 as originally proposed. Task 4 and 5 were addressed in 1984 as a means of reducing the environmental monitoring program for the interim period. Tasks 4, 5 and 6 should be ongoing efforts in the development of future monitoring programs for WRSOC.

8.4. PROGRAM RESULTS AND DISCUSSION

This section discusses in detail the work done on the tasks outlined in the Program Description and their relationship to the overall program objectives.

8.4.1. Assemblage of WRSP 1984 Environmental Data

A procedure was developed in 1983 to submit environmental data to the OSPO and WRSOC for computer storage. Each consultant was required to provide two computer tapes with copies of their data in sequential files along with tape and data file documentation to WRSOC. One tape was sent to the OSPO for their use and the other was sent to ERI for inclusion in the centralized data library.

During 1983, all the data from the initiation of the project in 1974 through 1982 were sent via computer tapes to the OSPO and to ERI through WRSOC. In 1984, the data collected in 1983 were similarly transmitted. The tapes and documentation for the 1983 environmental data were all received at ERI by the end of June, 1984.

8.4.2 Development and Maintenance of a Data Library and Cataloguing System-for WRSP Environmental Data

8.4.2.1 Introduction The data library was initiated in 1983 under the management of ERI. The library was designed to meet two objectives: 1) to provide a single integrated and efficient system for storing, retrieving and cataloguing all the WRSP environmental data, and 2) to provide a framework within which interdisciplinary data analyses could be performed. In 1984 the library format and procedures for handling data and associated documentation were formalized.

In meeting the two objectives, the library system was divided into two parts, a cataloguing section and an analysis section. Each section meets one of the two objectives of the library and has its own procedures. A flow

diagram showing the basic procedures in each section and their relationship to each other is shown in Figure 8.4-1.

8.4.2.2 Cataloguing Section The cataloguing section of the data library is designed to store and catalogue the data and have them ready for quick, efficient access for analysis or transmittal. It operates with a four step procedure that is initiated with the receipt of a data tape from WRSOC or WRSOC consultant.

Step One: The data tape and associated documentation are logged in the data tape and documentation log book. Each tape and documentation set are labeled with a unique number. This provides a record of the receipt by ERI of each data tape and its documentation.

Step Two: This step entails attempting to read the data tape on the computer. It is designed to ensure the creation of the tape was made without errors or problems. If the tape cannot be read, provisions are made to obtain another copy of the data.

Step Three: Once a data tape is successfully entered onto the computer, the files are stored in appropriate locations on disk for quick access and reference. If the data files are exceptionally lengthy, as is the case with the hourly meteorological data, then the data may not be stored on disk. In this case, these data files are put on disk only when necessary for analysis.

Step Four: In this step, a computerized catalogue of the data contained in each file is updated. The cataloguing system for the data library contains information on the type of data collected, initial and final sampling dates for each type of data, frequency of data collection,

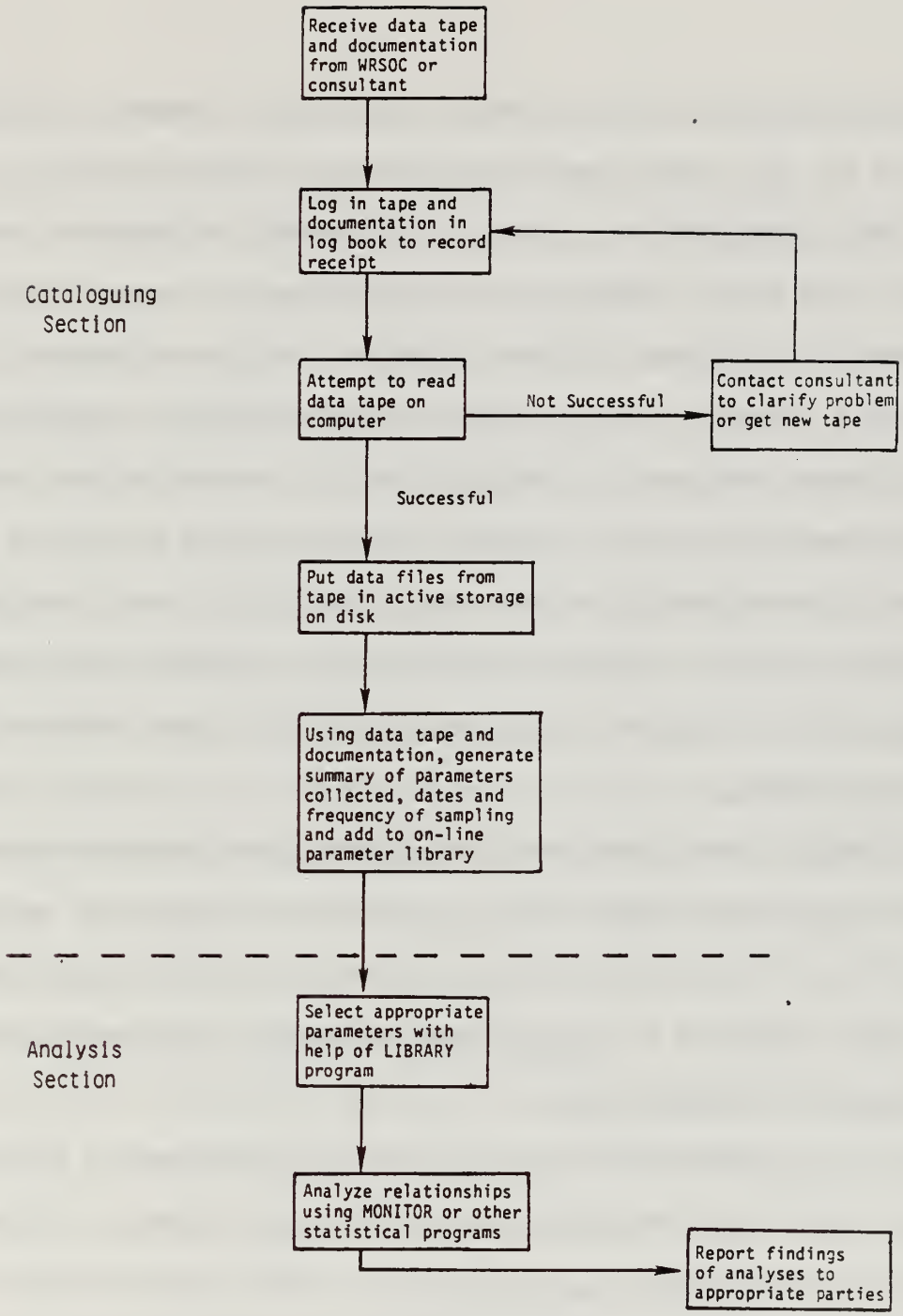

Figure 8.4-1. Flow diagram showing data management and library system.

location of sample site, consultant responsible for data collection, and name of the data file in which each data type may be found.

This information is entered on data sheets and then onto the computer on an annual basis. These data files can then be accessed by the program LIBRARY to provide the user with a summary of locations, dates, and collecting frequency for any parameter desired and the data files which contain this information. This provides the user of the data library with a tool for rapid location of any data that are desired for use or to determine whether a particular set of data was collected at a given location or during a specific period. This is useful in compiling data for the development of relationships. A detailed description of the program LIBRARY is contained in Section 8.4.3.

A sample coding sheet for the cataloguing file and a formal description of the fields on this coding form are contained in Appendix 8.A. In addition, lists of codes that are used in several of the columns are included. A section of the completed terrestrial resources cataloguing file also appears in Appendix 8.A.

All the environmental data submitted to WRSOC for the years 1974 through 1983 for air resources, aquatic biology, terrestrial fauna, vegetation, and water resources, have been catalogued into this system. A separate parameter file is maintained for the data from each discipline.

8.4.2.3 Analysis Section The second major objective of the data library is to provide a system for the analysis of the relationships between parameters to be used for monitoring. This is especially important when data from two or more disciplines are needed for an analysis but collected

by different consultants. Also the development of new relationships for monitoring may be important for more effective monitoring.

With the environmental database in a single, unified system, the development and analysis of relationships is made much easier as all the data may be accessed as needed. The development of effective software for analysis can then be undertaken to aid in the analysis process. Two programs have been written to aid in developing and analyzing relationships. LIBRARY was written to allow the user to locate desired data within the multitude of data files while MONITOR was written to provide a mechanism for comparing monitoring data with relationships developed from data collected during the baseline phase. These are discussed in more detail in Section 8.4.4. Other programs can be developed that will aid in accessing and doing analyses on the database to make the analysis section of the data library more effective. These programs should be outgrowths of needs that arise from the refining of the monitoring program.

8.4.2.4 Production of Tapes for WRSOC Storage A copy of the environmental data collected for WRSOC by its consultants for the period 1974 to 1983 was requested by WRSOC for storage at its facilities in Vernal. Two computer tapes containing all environmental data from the five individual disciplines were submitted to WRSOC in December of 1984. A report containing detailed documentation of these tapes and the data files contained on them was also submitted.

Data files are ordered on the data tapes by discipline in the following order:

TAPE 1

1. Water resources
2. Terrestrial fauna
3. Aquatic biology
4. Vegetation

Tape 2

1. Air resources

Within each discipline, files are arranged by type of data contained in the files. Within each file type, files are arranged in chronological order. Complete listings of data files on data tapes 1 and 2 are presented in Tables 8.4-1 and 8.4-2. Tape specifications are also included in the tables.

8.4.3 Development of Computer Software for Data Acquisition and Analysis

Programs essential for data acquisition and analysis were activated or developed to be used in conjunction with the data library. These programs can be broken down into three basic categories:

1. Two programs to copy data files to and from computer tape to the VAX-11 computer system at USU;
2. A program to allow the user to quickly locate a desired set of data or data type; and
3. A program to identify changes in the expected relationships of specified parameters.

The first two programs are utility programs for tape use on the VAX-VMS operating system. They are used for reading tapes onto the VAX (TAPECOPY)

Table 8.4-1. Content and specifications for Tape 1.

```
UNLABELED TAPE CREATED ON 20-NOV-84 18:20:08
        FIXED LENGTH RECORD =        90 CHARACTERS/REC
        PHYSICAL BLOCKSIZE =      3600 CHARACTERS/BLK
                   DENSITY =      6250 BPI
              CHARACTER SET =    ASCII
                     9 TRACK
```

FILE#	#RECS	SOURCE FILENAME:
1	1935	PPTEVAP.81;3
2	10781	DALYSURF.81;2
3	1313	DALYGRND.81;2
4	1948	DAILY.82;1
5	1227	DAILY.83;1
6	10142	INSTREV.81;1
7	3176	INSTSURF.81;2
8	4831	INSTGRND.81;2
9	614	INST.82;1
10	1235	INST.83;1
11	2770	WT75.VLD;1
12	3500	WT76.VLD;1
13	3820	WT77.VLD;1
14	3196	WT78.VLD;1
15	2746	WT79.VLD;1
16	2867	WT80.VLD;1
17	3762	WT81.VLD;1
18	2637	WT82.VLD;1
19	3176	WT83.VLD;1
20	262	BASEDEER.VLD;1
21	30	DEER82.LOC;1
22	44	DEER83.LOC;1
23	290	RIVER0482.LOC;1
24	444	RIVER0483.LOC;1
25	1734	RT75.VLD;1
26	3467	RT76.VLD;1
27	1950	RT77.VLD;1
28	2015	RT78.VLD;1
29	944	RT79.VLD;1
30	2013	RT80.VLD;1
31	6300	RT81.VLD;1
32	1618	RT82.VLD;1
33	1976	RT83.VLD;1
34	6345	ALL81.VLD;1
35	9168	BEAT82.VLD;1
36	6395	SWEEP82.VLD;1
37	15683	ALL83.VLD;2
38	108	ALL81.FGP;1
39	70	BEAT82.FGP;1
40	112	SWEEP82.FGP;1

Table 8.4-1. Cont.

FILE#	#RECS	SOURCE FILENAME:
41	185	ALL83.FGP;1
42	2368	BASELINE.VLD;1
43	488	PLANTWP83.VLD;1
44	146	SOILWP83.VLD;1
45	1023	ART81.VLD;2
46	547	ART82.VLD;1
47	234	ART83.VLD;1
48	996	NEM81.VLD;2
49	527	NEM82.VLD;1
50	200	NEM83.VLD;1
51	809	DIMENS80.VLD;1
52	946	DIMENS81.VLD;1
53	89	DIMENS82.VLD;1
54	800	FOLDIST80.VLD;1
55	625	FOLDIST81.VLD;1
56	595	ANNBICO83.VLD;1
57	1925	COVROCT83.VLD;1
58	389	SEEDPRO83.VLD;1
59	205	SEEDSOI83.VLD;1
60	190	WOODOCT83.VLD;1
61	88	NESTS.LOC;1
62	412	WILDLIFE.TAX;1
63	14	RODENTWTS.TAX;1
64	535	INSECTS.TAX;2
65	157	INVERTS.TAX;1
66	2507	8101PHYS.001;1
67	1351	8201PHYS.001;1
68	574	W012PHYSI.001;1
69	40	8101WCHEM.001;2
70	80	8201WCHEM.001;2
71	66	W012WCHEM.001;1
72	34	8101TURB.001;1
73	80	8201TURB.001;1
74	64	W012TURB.001;1
75	411	8101SEDSI.001;1
76	191	8201SEDSI.001;1
77	30	8201SEDSI.002;1
78	150	W012SEDSI.001;1
79	416	8101SEDOR.001;1
80	197	8201SEDOR.001;1
81	150	W012SEDOR.001;1
82	194	8101BENOR.001;2
83	207	8201BENOR.001;1
84	147	W012BENOR.001;1
85	69	8101DFTOR.001;2
86	54	8201DFTOR.001;3
87	62	W012DFTOR.001;1
88	2155	8101BENIN.001;1
89	1808	8201BENIN.001;1
90	2062	W012BENIN.001;1

Table 8.4-1. Cont.

FILE#	#RECS	SOURCE FILENAME:
91	412	W012BENIN.SUB;1
92	1320	8101DFTIN.001;1
93	444	8201DFTIN.001;1
94	39	W012DFTIN.001;1
95	599	8101PR.001;1
96	1344	8201PR.001;1
97	107	8201LEAF.001;3
98	42	W012LPACK.001;1
99	262	8101FLUOR.001;6
100	332	8201FLUOR.001;4
101	206	W012FLUOR.001;1
102	1538	8101PERI.001;5
103	1812	8201PERI.001;1
104	3712	W012PERI.001;2
105	51	ALGAE.VTN;1
106	1487	BENIN.VTN;1
107	1525	ANNBIOM.VLD;1
108	390	ANBI.83;1
109	150	BROWSE82.VLD;1
110	166	BRUT.83;1
111	38	BRCA.83;1
112	2645	COVDENF74.VLD;1
113	3516	COVDENF75.VLD;1
114	5326	COVDENS75.VLD;1
115	6290	COVDENS76.VLD;1
116	214	CRYPTO81.VLD;1
117	375	CRYPTO82.VLD;1
118	401	LIMO.83;1
119	58	LDR7576.TBL;1
120	986	LDRGROWTH.VLD;1
121	140	SALE.83;1
122	30	OTLE.83;1
123	42	LITTER81.VLD;1
124	155	LITTER82.VLD;1
125	473	LIFA.83;1
126	118	PERPROD.VLD;1
127	215	PERSTPJUN.VLD;1
128	319	SMICR081.VLD;1
129	252	SMICR082.VLD;1
130	229	SMICR7576.VLD;1
131	192	MIMO.83;1
132	319	SOILM81.VLD;1
133	24	BASESOILM.TBL;1
134	27	SAGECHEM.TBL;1
135	25	CHCO.83;1
136	240	PLANTCODE.TAX;2
137	54	LOCATIONS.LIS;1

Table 8.4-2. Content and specifications for Tape 2.

```
UNLABELED TAPE CREATED ON 20-NOV-84 22:25:28
        FIXED LENGTH RECORD =       132 CHARACTERS/REC
        PHYSICAL BLOCKSIZE =      3960 CHARACTERS/BLK
                  DENSITY =      6250 BPI
             CHARACTER SET =    ASCII
                   9 TRACK
```

FILE#	#RECS	SOURCE FILENAME:
1	79600	AIRQUAL.75;1
2	56500	AIRQUAL.76;1
3	27500	AIRQUAL.77;1
4	25600	AIRQUAL.78;1
5	25600	AIRQUAL.79;1
6	23300	AIRQUAL.80;1
7	21900	AIRQUAL.81;1
8	26300	AIRQUAL.82;1
9	25100	AIRQUAL.83;1
10	445	TSP.81;1
11	285	TSP.82;1
12	374	TSP.83;1
13	72	SOUND.82;1
14	71	SOUND.83;1
15	819	DOC7581.DAT;1
16	295	DOC82.DAT;1
17	293	DOC83.DAT;1

and for creating new tapes from sequential files (TAPECOPY). In general, they are not designed to be used on other computer systems and documentation of them is beyond the scope of this report. Most mainframe computers maintain their own versions of these utility programs.

The third program, called LIBRARY, was written in 1984 in FORTRAN by ERI. It is designed to allow users of the data library to determine the availability, location in the data base, sampling frequency, sample locations, and dates of collection of specified parameters. This is useful in determining what data are available for a specific analysis as well as helping to locate the data within the data files. A listing of the FORTRAN code and a sample output are contained in Appendix 8.B.

The computer program MONITOR is designed to provide a generalized capability to identify changes in the relationships between variables measured by the several contractors collecting data at the WRSOC site. The program does not contain any expected relationships; rather, it provides a means for collecting data from the contractors or data files, organizing data into a usable matrix, transforming variables as required to meet the requirements of statistical tests and performing a multiple linear regression on the baseline portion of the dataset. The post-disturbance portion of the dataset can be compared with the baseline regression and any significant deviations from the predisturbance condition will be identified. The program was developed under previous WRSOC contract and reactivated in 1983 for use in the data library.

8 4.4 Evaluation of Important Ecological Relationships

An important aspect of the WRSOC environmental monitoring programs as outlined in the EMM was to develop more sensitive methods for monitoring impacts due to oil shale development. Part of this effort was the construction of relationships between various components of the exosystem to reduce variability in a parameter and make it more sensitive for impact detection. This included the possibility of compiling data from two or more disciplines and facilitated a need for developing a central data library and software for compiling appropriate data for analysis.

In 1983 an evaluation of the relationships between annual plant biomass and sagebrush leader growth and various meteorological parameters was undertaken. This analysis produced some positive results in regards to the usefullness of sagebrush leader growth as a monitoring parameter and produced some doubts as to the effectiveness of annual plant biomass to detect impacts. Recommendations were made for an evaluation of the current parameters and the need for a more focused program that was designed to better detect impacts. This was in contrast to the majority of the existing program which was designed to gather a more complete baseline description of the system.

During 1984, WRSOC announced plans to reduce its development effort. It was decided at this time to put efforts scheduled for relationship development in developing an appropriate environmental program and to work toward a more focused program to be implemented when full scale operations resumed.

The outputs of the program review and the initial investigation into relationships were used to produce two documents for WRSOC to help them redirect their program.

The first document, 'WRSP Environmental Monitoring Program Considerations' outlined the philosophy for the 1985 program which was both cost-effective and environmentally sound. The philosophy maintained that the tract ecosystem had been adequately described, that the only impacts that had occurred were surface disturbances from construction and that monitoring should address only those areas that had been impacted or might be impacted in WRSOC's reduced operating plan. In addition, work should continue to further refine the monitoring program consistent with the philosophy of the EMM. Those ideas formed the basis for the program that was eventually proposed and accepted for 1985 by the OSPO.

The second document, entitled 'Guidelines for WRSP Environmental Program Redirection', was designed to help direct WRSOC in the development of a more focused and effective monitoring program. It will be discussed in more detail in the next section.

8.4.5 Pathway Identification

Pathway identification involves the identification of the pathways of movement of pollutants or perturbations through the ecosystem. It was recommended in the 1983 Ecosystem Analysis report that pathways for known pollutants be identified and that the monitoring program be designed to better detect them. This resulted in the production of the document, 'Guidelines for WRSP Environmental Program Redirection'.

This report outlined the philosophy of using pathway identification for monitoring and reviewed the basic pollutants that are expected from oil shale development. It recommended that each consultant review the literature to determine the potential pathway of these pollutants through their component of the ecosystem and identify parameters that would be sensitive enough to help determine the effects of these pollutants on the environment.

Pathway identification was also used to help develop the 1985 environmental monitoring program proposed and accepted by the OSPO. By considering the potential pollutants and perturbations of the reduced development program, a monitoring program was developed that addressed those specifically. The philosophy behind this effort was included in the document 'WRSP Environmental Monitoring Program', prepared for WRSOC.

8.4.6 Program Recommendations

The WRSP environmental monitoring program recommendations based on the work of the 1984 Ecosystem Analysis program are listed below. These, in combination with the program recommendations summarized in the 1983 Ecosystem Analysis report, should be used in evaluating and redirecting the overall program.

The following are recommendations for the environmental monitoring program:

1. Work toward a single, integrated environmental monitoring program should continue;

2. Monitoring effects should be directed toward detecting impacts and away from baseline description,

3. Work should continue to develop a set of parameters for monitoring in each discipline that are sensitive to the potential impacts of oil shale development.

Appendix 8.A

This appendix contains documentation for the parameter cataloguing files. These files contain information on the parameters, dates, sampling locations, sampling frequency and consultant for all the environmental data collected in the WRSP environmental program. They also contain information on the data files and computer tapes which contain each type of data.

A separate file is generated for each consultant. A list of the file names appear in Table 8.A-1. These files are used as necessary input to the program LIBRARY.

A partial listing of the cataloguing file for Bio-Resources, Inc. is shown in Figure 8.A-1. The column identities can be obtained by looking at the coding form shown in Figure 8.A-2. A complete description of the fields contained in this coding form is contained in Table 8.A-2.

Table 8.A-1. List of cataloguing files names.

Consultant	File Name
Aerovironment	PARMDATES.AVI
Bio-Resources, Inc.	PARMDATES.BRI
Ecosystems Research Inst.	PARMDATES.ERI
Native Plants, Inc.	PARMDATES.NPI
VTN	PARMDATES.VTN

04	21	06	0401	760602	761012	D	04	RT76.VLD
04	22	06	0401	760602	761012	D	04	RT76.VLD
04	23	06	0401	760602	761012	D	04	RT76.VLD
04	24	06	0401	760602	761012	D	04	RT76.VLD
04	16	06	0402	760616	761012	D	04	RT76.VLD
04	17	06	0402	760616	761012	D	04	RT76.VLD
04	18	06	0402	760616	761012	D	04	RT76.VLD
04	19	06	0402	760616	761012	D	04	RT76.VLD
04	20	06	0402	760616	761012	D	04	RT76.VLD
04	21	06	0402	760616	761012	D	04	RT76.VLD
04	22	06	0402	760616	761012	D	04	RT76.VLD
04	23	06	0402	760616	761012	D	04	RT76.VLD
04	24	06	0402	760616	761012	D	04	RT76.VLD
04	15	06	0101	770208	770808	D	04	RT77.VLD
04	16	06	0101	770208	770808	D	04	RT77.VLD
04	17	06	0101	770208	770808	D	04	RT77.VLD
04	18	06	0101	770208	770808	D	04	RT77.VLD
04	19	06	0101	770208	770808	D	04	RT77.VLD
04	20	06	0101	770208	770808	D	04	RT77.VLD
04	21	06	0101	770208	770808	D	04	RT77.VLD
04	22	06	0101	770208	770808	D	04	RT77.VLD
04	23	06	0101	770208	770808	D	04	RT77.VLD
04	24	06	0101	770208	770808	D	04	RT77.VLD
04	15	06	0102	770208	770808	D	04	RT77.VLD
04	16	06	0102	770208	770808	D	04	RT77.VLD
04	17	06	0102	770208	770808	D	04	RT77.VLD
04	18	06	0102	770208	770808	D	04	RT77.VLD
04	19	06	0102	770208	770808	D	04	RT77.VLD
04	20	06	0102	770208	770808	D	04	RT77.VLD

Figure 8.A-1. Sample of terrestrial fauna resources cataloguing file.

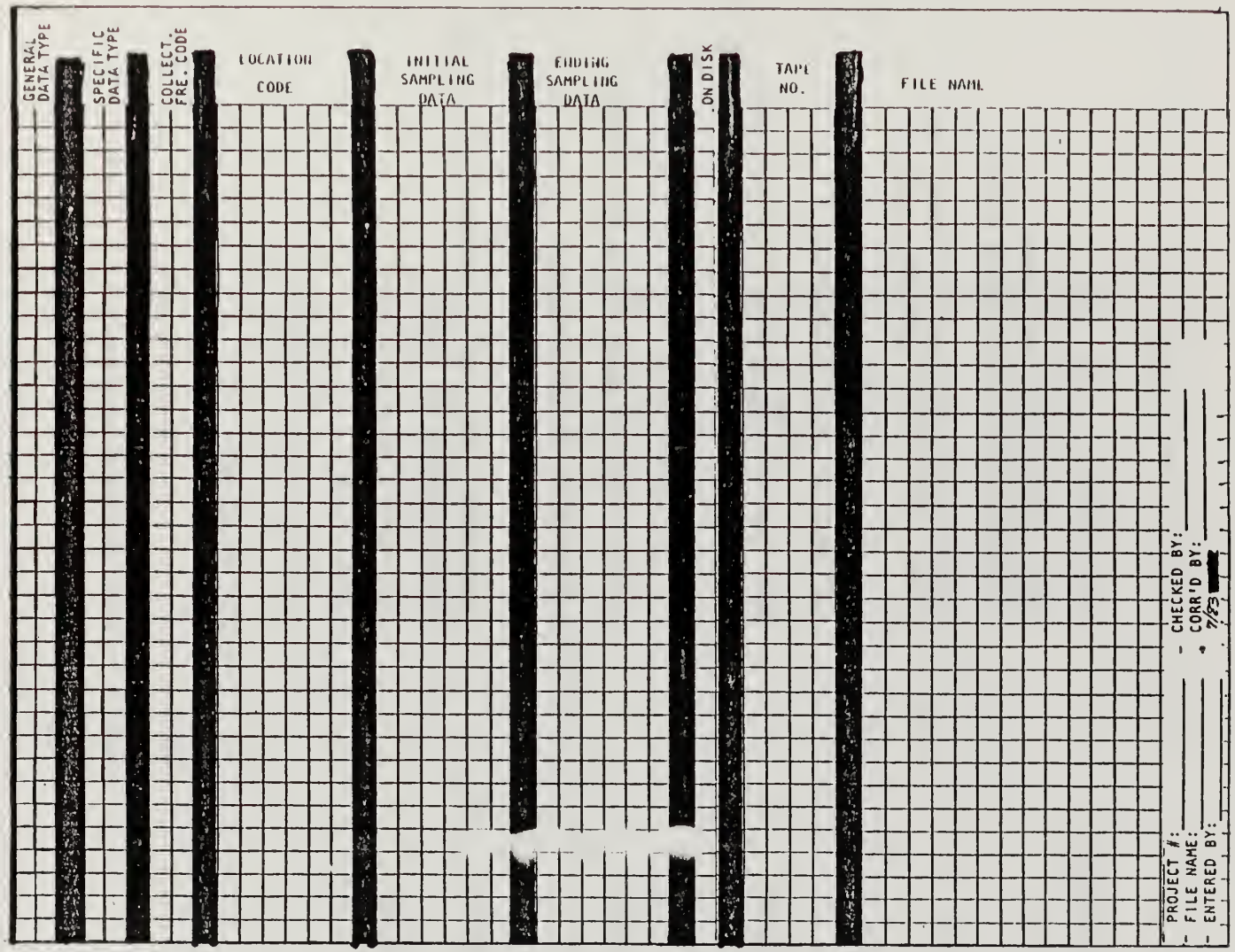

Figure 8.A-2. Sample library coding sheet.

Table 8.A-2. Field descriptions for cataloguing files.

Column(s)	Description
1-2	Code identifying organization that collected data (see Table 8.A-3)
4-5	Code identifying specific data type (see Table 8.A-4 through 8.A-8)
7-8	Code representing frequency of sample collection (see Table 8.A-3)
10-15	Code identifying sample location (see enclosed map and Tables 8.A-9 through 8.A-11)
17-22	Initial sampling date for data (YYMMDD)
24-29	Ending sampling date for data (YYMMDD)
31	D = on disk in ERI library (blank) = not on disk in ERI library
33-36	Tape number assigned to original data tape when received by ERI
38-80	File name containing data

Table 8.A-3. Primary codes for data library.

Primary Codes For Data Library

Code Identifying Organization

01	Aerovironment
02	VTN
03	Native Plants Inc.
04	Bio-Resources Inc.
05	Ecosystems Research Institute

Collection Frequency Code

01	Hourly
02	Daily
03	Weekly
04	Biweekly
05	Monthly
06	Bimonthly
07	Quarterly
08	Semi-annua y
09	Annually
10	Once only
11	3 or 4 tim every week to 10 days

Locat on Codes

See map and list of codes not occurring on map

9999 Location not applicable

Date Codes

000000 Date not applicable

Map Color Codes

Aerovironment	Black
Bio-Resources Inc.	Brown
Ecosystems Research Inst.	Blue
Native Plants Inc.	Green
VTN	Red

Table 8.A-4. Parameter codes and descriptions of data collected by Aerovironment, Inc. (AVI).

Unit Codes Are Included In The Data (See Appendix 8.A.22)

Code Number	Parameter
1	Wind speed at 10 m
2	Wind direction at 10 m
3	Temperature
4	Total hydrocarbons
5	Hydrocarbons - corrected for CH_4
6	Methane
7	Carbon monoxide
8	Nitric oxide
9	Nitrogen dioxide
10	Oxides of nitrogen
11	Ozone
12	Total sulfur
13	Hydrogen sulfide
14	Sulfur dioxide
15	Wind speed at 20 m
16	Wind direction at 20 m
17	Wind speed at 30 m
18	Wind direction at 30 m
19	Delta T (measure of vertical atmospheric stability)
20	Sigma theta (measure of wind direction stability)
21	Sigma W
22	Coefficient of haze
23	Dew point
24	Scattering Coefficient
25	Cloud cover
26	Barometric pressure
27	Net solar radiation, sky - ground
28	Radiation - ion pressure chamber
29	---
30	Relative humidity
40	Total suspended particulates
41	Sound levels (dbls)

Table 8.A-5. Parameter codes and descriptions of data collected by Bio-Resources, Inc. (BRI).

Code Number	Parameter	Units
1	Number of soil invertebrate taxa present	
2	Total fresh weight of soil invertebrates	.01g
3	Weight of nematode subsample	.01g
4	Weight of arthropod subsample	.01g
5	Total dry weight of soil invertebrates	.01g
6	Plant height	cm
7	Plant diameter	cm
8	(II/JJ) portion of nematode extract counted	
9	(II/JJ) portion of arthropod extract counted	
10	Soil temperature	°C
11	Soil invertebrate taxa present (codes defined in INVERTS.TAX)	
12	Number of each soil invertebrate taxon present	
13	Soil invertebrate identification codes and corresponding scientific names (class, order, suborder, family, genus, species)	
14	Soil invertebrate trophic level code 1=herbivore; 2=carnivore; 3=detritivore; 4=bacterivore; 5=omnivore	
15	Condition of rodent traps 1=sprung,empty; 2=inoperative; 3=insensitive treadle release; 4=missing	
16	Species of rodent trapped	
17	Physical condition of rodent T=torpid; D=dead; blank=OK	
18	Age of organism J=juvenile; A=adult; blank=unknown	
19	Sex of organism M=male; F=female; blank=unknown	
20	Reproductive condition of rodent P=pregnant; L=lactating; blank=other	
21	Tag code or toe clip number of rodent	
22	Weight of individual organism	1g
23	Grid type code (See Appendix 8.A.1)	

Bio-Resources, Inc. (Continued)

Code Number	Parameter	Units
24	Day number of session (session usually = 5 days)	
25	Minimum expected adult rodent weight by species	g
26	Maximum expected adult rodent weight by species	g
27	Min. expected juvenile rodent weight by species	g
28	Max. expected juvenile rodent weight by species	g
29	Mean adult male rodent weight by species	g
30	Mean juvenile male rodent weight by species	g
31	Mean adult female rodent weight by species	g
32	Mean pregnant female rodent weight by species	g
33	Mean juvenile female rodent weight by species	g
34	Species of plant or type of substrate	
35	Phenological stage of shrub insect host plant (See Appendix 8.A.2)	
36	Taxon code of shrub insect (See Appendix 8.A.3)	
37	Functional group of shrub insects (see Appendix 8.A.4)	
38	Number of each taxon of shrub insects captured on host plant	
39	Host plant code (See Appendix 8.A.5)	
40	Weight of insects caught in each functional group	g
41	Cloud cover (1-4 : 25% intervals)	
42	Air temperature	°C
43	Wind direction	
44	Wind speed	km/hr
45	Life stage of shrub insect 0=undetermined (for spiders & ticks) 1=egg 2=larva 4=pupa 3=nymph 5=adult	
46	Age group of shrub insects (see Life stage; Code #45)	
47	Feeding type of shrub insects (See Appendix 8.A.4)	

Bio-Resources, Inc. (Continued)

Code Number	Parameter	Units
48	Full name and/or description of shrub insect taxon	
49	Life form of plants (See Appendix 8.A.6)	
50	Perpendicular diameter of plant	cm
51	Radius of sample circle	dm
52	Substrate code for wildlife sightings (See Appendix 8.A.7)	
53	Percent of plant or substrate cover	
54	Presence or absence of foliage at each height interval: .1 meter intervals from 0-.4m; .5 meter intervals from .5-5.5 meters	
55	Taxon of wildlife (order, family, genus, species) (genus & species only in some cases)	
56	Wildlife functional group code - obsolete	
57	Guild designation for birds (See Appendix 8.A.8)	
58	Consuming biomass for birds	1g
60	Type of wildlife observation 1=seen; 2=heard; 3=sign	
61	Number of wildlife individuals (only if seen)	
62	Perpendicular distance of organism from transect (if seen) (+=right; -=left)	m
63	Activity code (See Appendix 8.A.9)	
64	Type of shrub insect sampling 1=sweep; 2=beating;	
65	Time of day and taxa emphasized 1 = morning for birds 2 = evening for mammals 3 = afternoon for reptiles	
66	Type of wildlife sighting 1=opportunistic; 0=regular transect walk	
67	Total number of wildlife seen in a group	
68	Number of bucks, does, fawns in group	
69	Radio frequency of individual	

Bio-Resources, Inc. (Continued)

Code Number	Parameter	Units
70	Habitat/vegetation type 1 = greasewood/sagebrush 2 = juniper 3 = shadscale 4 = riparian	
71	Aspect of slope (N, NE, E, SE ... etc.)	
72	Mileage of wildlife sighting on river transect	.1 mi
73	Soil temperature in sun if first measurement was in shade	°C
74	Coordinates of rodent trap station (XXY) XX = column number from west to east Y = row number (in hexadecimal) from south to north	
75	Number of plant individuals	
76	Number of seeds counted	
77	Number of flowers examined for seeds	
78	Number of flowers counted	
79	Number of inflorescences examined for flowers	
80	Number of inflorescences counted	
81	Dry weight of annual plant biomass harvested	.01 g
82	UTM coordinates	.01 km
83	Description of raptor nest LSN = large stick nest SSN = small stick nest GHO = great horned owl TVN = turkey vulture nest PFN = prairie falcon nest	
84	Raptor nest substrate C = cliff T = tree G = ground	
85	Height of nest above base of cliff or tree	m
86	Distance from nest to top of tree or cliff	m
87	Aspect (to nearest 5 degrees)	

Bio-Resources, Inc. (Continued)

Code Number	Parameter	Units
88	Geologic formation U = Uinta sandstone G = Green River	
89	Nest configuration F = face of cliff (no overhang) L = ledge (an overhanging ledge) C = cave (deep depression with sides) V = vertical crack (entered from below)	
90	View from nest O = open (broad landscape view) C = closed (cut off by canyon walls, etc.)	
91	Status, condition, and fate of active nests (see Appendix 8.A.16)	
92	Length of current year's stem growth	mm
93	Portion of canopy harvested	NN/DD
94	Oven-dry weight of portion of canopy harvested	.01 g
95	Depth of soil psychrometer	cm
96	Psychrometer chamber temperature	°C
97	Zero offset	uv
98	Cooling time	sec
99	First microvolt reading	uv
A1	Dewpoint	uv
A2	Second microvolt reading	uv
A3	Plant water potential	-1 bars
A4	Soil water potential	-1 bars

Table 8.A-6. Parameter codes and descriptions of data collected by Ecosystems Research Institute, Inc. (ERI).

Code Number	Parameter	Units
1	Distance along transect of sampling site	m
2	ERI sample log number	
3	Sample number of replicates - blank=no replicates	
4	Percent of sample actually identified	
5	Type of sampler used (See Appendix 8.A.10)	
6	Taxon of benthic invertebrates (order, family, genus, species) (See Appendix 8.A.11)	
7	Life stage code (See Appendix 8.A.11)	
8	Length of individual organism	mm
9	Number of individuals	
10	Wet weight of organic sample	g
11	Dry weight of organic sample	g
12	Percent of original sample dried	
13	Time drift net placed in river	24 hr clock
14	Time drift net removed from river	24 hr clock
15	Type of drift net used	

Code	Sampler	Area Sampled (cm^2)
C	Cowdell	1393.5
D	Designer	520.8
R	Round	506.7
S	Square	1393.5

16	Velocity of water at mouth of net	cm/s
17	Depth of top of drift net	cm
18	Area of net opening used, blank=entire area used	cm^2
19	Chlorophyll a (mg/m^2 for benthic samples) (mg/l for water samples)	
20	Pheophytin a (mg/m^2 for benthic samples) (mg/l for water samples)	
21	Volume of sample extracted	ml

Ecosystem Research Institute (Continued)

Code Number	Parameter	Units
22	Taxon of periphyton (phylum, genus) (See Appendix 8.A.12)	
23	Diameter of algal cell	whipple disc
24	Length of algal cell	whipple disc
25	Number of algal cells	
26	Field number of multiple microscope fields counted	
27	Number of microscope fields counted	
28	Microscope objective lens magnification	
29	Volume of subsample	ml
30	Code for area of microscope field counted F = entire microscope field D = 100 squares of whipple disc	
31	Time of sampling	24 hr clock
32	Air Temperature	°C
33	Water Temperature	°C
34	Cloud cover	%
35	Depth intervals of velocity samples	cm
36	Code for sample location (w = edge of water, * = benthic sample)	
37	Stadia rod reading from level	cm
38	Velocity of water at surface and at depth intervals below surface	cm/sec
39	Code of most abundant substrate at survey location (see Appendix 8.A.13)	
40	Percent of bottom at survey location consisting of most abundant substrate	
41	Code of second most abundant substrate at survey location (See Appendix 8.A.13)	
42	Percent of bottom at survey location consisting of second most abundant substrate	
43	Depth of rock in chamber below water surface	cm
44	Light reaching rock surface	lux

Ecosystem Research Institute (Continued)

Code Number	Parameter	Units
45	Change in oxygen in chamber	mg/l
46	Dry weight of periphyton on rock	g
47	Rock volume	l
48	Surface area of rock	cm^2
49	Crucible weight	gm
50	Weight of crucible plus sample pre-ignition	g
51	Weight of crucible plus sample post-ignition	g
52	Dry weight of sediment size fractions (See Appendix 8.A.14)	g
53	Absorbance at 750 nm (unacid,.001); 663 nm (unacid, .001); 645 nm (unacid,.001); 630 nm (unacid,.001)	
54	Fraction of light transmitted at 660nm, 750 nm, 435 nm, 630 nm, 645nm	
55	Total phosphorus	ug/l
56	Total dissolved phosphorus	ug/l
57	Particulate phosphorus	ug/l
58	Orthophosphate	ug/l
59	Nitrate (NO_3)	ug/l
60	Nitrite (NO_2)	ug/l
61	Ammonia (NH_3)	ug/l
62	Total inorganic nitrogen	ug/l
63	Total dissolved solids	mg/l
64	Total suspended solids	mg/l
65	Conductivity	umhos/cm
66	pH	
67	Leaf pack number C=coarse mesh container, F=fine mesh container	
68	Date leaf pack placed in river	
69	Date leaf pack removed from river	

Ecosystem Research Institute (Continued)

Code Number	Parameter	Units
70	Dry weight of leaves in leafpack when placed in river	.01g
71	Dry weight of leaves in leafpack when removed from river	.01g
72	Total degree days of water leafpack subjected to	
73	Total days leafpack in river	
74	Total time respiration measured columns 51-52 minutes columns 53-54 seconds	
75	Initial reading of oxygen meter	mgO_2/l
76	Final reading of oxygen meter	mgO_2/l
77	Percent of sample filtered	%
78	Fluorescence	.1 fluorescence unit
79	Acid fluorescence	.1 fluorescence unit
80	Volume of sample filtered	ml
81	Dilution factor, blank if not diluted	
82	Substance analyzed for metal concentration (see Appendix 8.A.21 for codes)	
83	Concentration of cadmium	ug/g dry weight
84	Concentration of chromium	ug/g dry weight
85	Concentration of copper	ug/g dry weight
86	Concentration of lead	ug/g dry weight
87	Concentration of nickel	ug/g dry weight
88	Concentration of zinc	ug/g dry weight

Table 8.A-7. Parameter codes and descriptions of data collected by Native Plants, Inc. (NPI).

Code Number	Parameter	Units
1	% cover annual vegetation - all species	.01%
2	Dry biomass annual vegetation - all species	.01 g
3	Annual increment of leader growth - *Artemisia tridentata*	1 mm
4	Annual increment of leader growth - *Atriplex canescens*	.1 mm
5	Annual increment of leader growth - *Juniperus osteosperma*	1 mm
6	Annual increment of leader growth - *Sarcobatus vermiculatus*	1 mm
7	Annual increment of leader growth - *Chrysothamnus nauseosus*	1 mm
8	Annual increment of leader growth - *Atriplex confertifolia*	1 mm
9	Dry biomass of perennial and late annual vegetation for each taxon	.01 g
10	Frequency of occurrence of taxon in 100 samples	
11	Species present in perennial vegetation plots	
12	Percent cover for each taxon on steep juniper plots	.0001%
13	Percent soil moisture, gravimetric measurement	.1%
14	Soil pH	.01 unit
15	Soil electrical conductivity	.01 mmhos/cm
16	Fungi	m hyphae/g soil
17	Bacteria	$.1 \times 10^6$ cells/g soil
18	Respiration SMICR081.VLD; SMICR082.VLD SMICR7574.VLD	 $.1 \times 10^{-4}$m equiv. CO_2/g hr 10^{-1} moles CO_2/g min
19	Dehydrogenase activity SMICR081.VLD; SMICR082.VLD SMICR7576.VLD	 .1 mg formazan/liter 10^3 mg formazan/ml
20	% organic carbon	.01%
21	Depth of sampling	cm
22	Depth code (1=0-5 cm; 2=5-15 cm)	

ORGANIZATION - NP (NATIVE PLANTS, INC.)

Code Number	Parameter	Units
23	Soil water potential	-.1 bars
24	Proteolytic activity	.1% hydrolysis
25		
26	Nitrogen - fixing potential	.001 N_2/hahr
27	Nitrification potential at surface	.1 ugN/g soil
28	Aerobic bacteria	10^5/g soil
29	Anaerobic bacteria	10^3/g soil
30	Streptomycetes	10^4/g soil
31	Total NH_4-N	.1 ugN/g soil SMICR7576.VLD ugN/g soil SOILM81.VLD
32	Fixed NH_4-N	.1 ugN/g soil
33	Exchangeable NH_4-N	.1 ugN/g soil
34	Total N SMICR7576.VLD, BASESOILM.TBL SOILM81.VLD	.01% %
35	NO_3-N SMICR7576.VLD, BASESOILM.TBL SOILM81.VLD	.1 ugN/g soil ugN/g soil
36	(ATP) at surface	10^{-3} ug ATP/g soil
37	NO_2-N	ugN/g soil
38	% sand SOILM81.VLD BASESOILM.TBL	.1% 1%
39	% clay SOILM81.VLD BASESOILM.TBL	.1% 1%
40	% silt	1%
41	Soil texture S=sandy, SL=sandy loam, LS=loamy sand	
42	% of particles larger than 2mm diameter	1%
43	$CaCO_3$	.1%
44	Moisture tension	.1% at 1/3 atmosphere
45	Moisture tension	.1% at 15 atmosphere
46	Saturation moisture percentage	1%
47	Available phosphorus	.1 ppm

ORGANIZATION - NP (NATIVE PLANTS, INC.)

Code Number	Parameter	Units
48	Extractable Mg by NH_4Ac	me/100g
49	Extractable Na by NH_4Ac	
50	Extractable K by NH_4Ac	
51	Exchangable Mg by NH_4Ac	me/100g
52	Exchangable Na by NH_4Ac	
53	Exchangable K by NH_4Ac	
54	Water soluble Mg by NH_4Ac	me/100g
55	Water soluble Na by NH_4Ac	
56	Water soluble K by NH_4Ac	
57	Mean of sagebrush leader growth per plant 1975 - from 10 observations 1976 - from 20 observations	.1mm
58	One standard deviation of sagebrush leader growth per plant	.01mm
59	Mean of sagebrush leader growth of all plants for each site	.1mm
60	One standard deviation for site means	.01mm
61	Plant taxa codes and their definitions	GGGSSS
62	Location codes and their corresponding UTM coordinates	
63	Cage Class of browse shrubs 1 = no cage, 2 = uncaged	
64	Form class of available twigs 1 = not hedged, 2 = lightly to moderately hedged, 3 = severely hedged, 4 = dead	
65	Age class 1 = seedling, 1/8" or less; 2 = young, 1/8"-1/2"; 3 = mature, over ½"; 4 = decadent, 25% of crown dead	based on stem diameter
66	Percent of leaders utilized	1%
67	Height of vegetation	1 cm
68	Cover of all vegetation on vegetation plots	$cm^2/4m^2$
69	Density of vegetation (not available for all species)	number/$4m^2$
70	Lifeform of vegetation	added by software from taxon

ORGANIZATION - NP (NATIVE PLANTS, INC.)

Code Number	Parameter	Units
71	Cryptogamic taxa or groups present	
72	Commonness factor of cryptogamic taxa or groups 1 = rare; 2 = common; 3 = abundant	not for all taxa
73	Frequency of occurrence of cryptogamic taxa in each quarter of sampling quadrats	
74	Ocular estimate of % of total cryptogamic cover occupied by each group in each quadrat groups = mosses, algae, terricolous lichens, saxicolous lichens	1%
75	total % cover of cryptogamic species	1%
76	Species of lichen present	
77	Percent cover of all lichen species combined	1%
78	Presence or absence of each lichen taxon 1 = present, blank = absent	
79	% cover of *Leanora peltata*	1%
80	Maximum diameter of shrub	1 cm
81	Perpendicular diameter of shrub	1 cm
82	Total litter dry weight	.1g
83	Size of catchment	1 = 1 m^2 2 = .5 m^2
84	Leaf litter dry weight	.1 g
85	Stem litter dry weight	.1 g
86	Seed litter dry weight	.1 g
87	Inflorescence litter dry weight	.1 g
88	Inseparable litter dry weight	.1 g
89	Content of Molybdenum in sagebrush stem leaders	.01 ppm
90	Content of Arsenic in sagebrush stem leaders	.1 ppm
91	Content of Magnesium in sagebrush stem leaders	1 ppm
92	Content of Cadmium in sagebrush stem leaders	.1 ppm
93	Content of Mercury in sagebrush stem leaders	1 ppb
94	Content of Boron in sagebrush stem leaders	1 ppm
95	% content of sodium in sagebrush stem leaders	.001 %
96	% content of calcium in sagebrush stem leaders	.001 %
97	% content of sulfate in sagebrush stem leaders	.01 %
98	Number of diatoms	#/g soil

Table 8.A-8. Parameter codes and descriptions for data collected by VTN, Inc.

Code Number	Parameter	Units
1	Mean daily water level	feet below LSD
2	Maximum daily water temperature	^{o}C
3	Minimum daily water temperature	^{o}C
4	Mean daily water temperature	^{o}C
5	Mean daily discharge	cfs
6	Maximum daily value for specific conductance	umhos at $25^{o}C$
7	Minimum daily value for specific conductance	umhos at $25^{o}C$
8	Mean daily value for specific conductance	umhos at $25^{o}C$
9	Mean daily suspended sediment concentration	mg/l
10	Mean daily suspended sediment discharge	tons/day
11	Water temperature measured at random hour	^{o}C
12	Specific conductance measu d at random hour	umhos at $25^{o}C$
13	Time of data collection	24 hour clock
14	Water quality parameter coo :	see Appendix 8.A.15
15	Values of water quality pa meters	collected continuou ly or once daily
16	Value of water quality para meter at a particular instant in time	
17	Accumulated precipitation	inches monthly total
18	Accumulated precipitation	inches daily total
19	Accumulated evaporation	inches monthly total
20	Medium code	see Appendix 8.A.17
21	Analysis status code	see Appendix 8.A.18
22	Hydrologic event code	see Appendix 8.A.19
23	Hydrologic condition code	see Appendix 8.A.20

Table 8.A-9. Location codes not occurring on map for Bio-Resources, Inc. (BRI).

In vegetation type but not on transect:

Codes	Vegetation Type
01,0100	greasewood
02,0200	juniper
03,0300	shadscale
04,0400	riparian

Other:

Location Code	Location
WRBR	White River Bridge (approx. UTM 655.7 4426.9)
SOCYN	near summit of Southam Canyon (approx. UTM 653. 4418.)
RAGTOP	near SE corner of section 23 (approx. UTM 655.8 4421.2)
EVACR	Evacuation Creek Bridge (approx. UT 657.5 4423.9)
DUCK	Duck Rock, near Ua entrance (approx. UTM 657.1 4424.5)

Table 8.A-10. Location codes not occurring on map for Ecosystems Research Inst. (ERI).

Location Code	Location
WR	anywhere on White River
EC	anywhere on Evacuation Creek
CC	Same as WR98
TD01	on White River above Taylor's Draw
TD02	on White River below Taylor's Draw
AW	anywhere in Asphalt Wash
EC00	on Evacuation Creek upstream from EC01
ABEC	on White River above Evacuation Creek
ABAW	on White River above Asphalt Wash

Table 8.A-11. Location codes not occurring on map for VTN, Inc.

Location Code	Location
6417	no information available
RA2	precipitation storage gauge
RA8	precipitation storage gauge
RA13	precipitation storage gauge in Plant Site Wash
RP1	precipitation storage gauge near mouth of Evacuation Creek
RS4	precipitation storage gauge near mouth of Plant Site Wash
RS7	precipitation storage gauge 2 miles east of Evacuation Creek
RS8	precipitation storage gauge in upper Evacuation Creek
RS9	precipitation storage gauge in upper Southam Canyon
RS15	precipitation storage gauge
EVP6	evaporation pan

Table 8.A-12. Location codes not occurring on map for AVI.

Code	Sound Monitoring Stations
S1	Highway 45 #1
S2	Ignacio #1
S5	Ignacio #2
S7	Highway 45 #2
S8	Asphalt Wash

Appendix 8.A.1

Grid Type

Code	Grid Configuration	Spacing
1	1x25	40 m
2	2x12	15x15 m
3	5x5	15x15 m
4	12x12	15x15 m
5		
6	6x12	15x15 m
7	1x25	15 m
8	12x2	15x0
		(pairs at 12 stations)

Appendix 8:A.2

Phenological Stage of Shrub Insect Host Plant

BASELINE.VLD

BLOOM = in bloom

NBLOM = not in bloom

OLDBLO = late bloom stage

BUD = bud stage

BEAT82.VLD

1 = dormant

2 = leaf buds

3 = new leaf growth

4 = floral buds

5 = flowering

6 = seeds

7 = fall dormancy

8 = post - flower leaf growth

Appendix 8.A.3

Taxon Code of Shrub Insects

000 #FFFGGGSSS

0 = code for order

= number indicating if next lowest level is

1 = suborder

2 = superfamily

3 = family

F = code for taxonomic level indicated in preceding column

G = code for genus

S = code for species

codes defined in INSECTS.TAX

Appendix 8.A.4

Functional Groups of Shrub Insects

1 = predators/chewers
2 = predators/suckers
3 = parasites
4 = leaf - feeders
5 = sap - feeders
6 = saprophores
7 = omnivores (ants)
8 = non - feeders
9 = flower feeders
10 = various Diptera

Appendix 8.A.5

Host Plant Code

1 = Artemisia tridentata
2 = Chrysothamnus nauseosus
3 = Chrysothamnus viscidiflorus
4 = Sarcobatus vermiculatus
5 = Juniperus osteosperma
6 = Atriplex confertifolia
7 = Tetradymia spinosa
8 = Grayia spinosa
9 = Bromus tectorum
10 = (Bunchgrasses)
11 = Populus fremontii
12 = Artemisia nova (shrub insect data only)
12 = Atriplex canescens
13 = Bassia hyssopifolia
14 = Rhus trilobata
15 = Salix exigua
16 = Tamarix pentandra
17 = Cleome lutea
18 = Chorispora tenella
19 = Descurainia sophia
20 = Sphaeralcea coccinea
21 = Artemisia ludoviciana
22 = Salsola kali
23 = Mentzelia albicaulis
24 = Holodiscus microphyllus
25 = Asclepias cryptoceras
26 = Grindelia squarrosa
27 = Guiterrezia sarothrae
28 = Eriogonum microthecum
29 = Cleome serrulata
30 = Lepidium montanum
31 = Populus fremontii
32 = Amelanchier utahensis
33 = Gilia sp.
34 = Halogeton glomeratus

Appendix 8.A.6

Life Form of Plants

1 = evergreen tree
2 = deciduous tree
3 = evergreen shrub
4 = deciduous shrub
5 = evergreen spinescent shrub
6 = deciduous spinescent shrub
7 = caespitose woody shrub
8 = perennial herb
9 = annual/biennial
10 = succulent
11 = unknown life form
12 = bare ground
13 = woody vine
14 = undefined
15 = litter
16 = dead wood
17 = cottonwood
18 = willow

Appendix 8.A.7

Substrate Code for Wildlife Sightings

1 = ground
2 = herbs
3 = shrub base
4 = shrub canopy
5 = tree trunk
6 = tree limb
7 = tree foliage
8 = air
9 = water
10 = rock outcrop/cliff
11 = artificial perch

Appendix 8.A.8

Guild Designation for Birds

first column	second column	third column
G = ground	G = gleaning	G = granivore
A = air	C = cruising	O = omnivore
B = bark	H = hawking	I = insectivore
F = foliage	P = probing	

any column
N = nectarivore
R = raptor

Appendix 8.A.9

Activity Code

1 = flying/running
2 = stationary
3 = feeding
4 = mating
5 = drinking
6 = agonistic
7 = other
8 = local movement

Appendix 8.A.10

Type of Sampler Used

code	type of sampler	area sampled (cm^2)
HE	Hess	1320.0
HS	New Hess	1297.0
SU	Surber	930.3
MS	Modified Surber	929.0
CT	Clear tube	16.6
3C	3 Clear tube	49.8
BT	Blue tube	88.2
SB	Substrate Basket	

Appendix 8.A.11

Aquatic Insects

CODE	LIFE[1] STAGE	FUNCT[2] GROUP	WEIGHT[3] CURVE	ORDER	FAMILY	GENUS
COLAMP		3	1	COLEOPTERA	AMPHIZOIDAE	
COLDYTHYD		3	1	COLEOPTERA	DYTISEIDAE	HYDATICUS
COLELM		4	1	COLEOPTERA	ELMIDAE	
COLHAL		1	1	COLEOPTERA	HALIPLIDAE	
COLHYDHYD	LA	3	1	COLEOPTERA	HYDROPHILIDAE	HYDROPHILUS
COLHYDHYD	AD	4	9	COLEOPTERA	HYDROPHILIDAE	HYDROPHILUS
CLLISOISO		4	9	COLLEMBOLA	ISOTOMIDAE	ISOTOMURUS
DIPCHI		4	2	DIPTERA	CHIRONOMIDAE	
DIPCUL		4	2	DIPTERA	CULICIDAE	
DIPEMPCHE		4	2	DIPTERA	EMPIDIDAE	CHELITERA
DIPEMPHEM		4	2	DIPTERA	EMPIDIDAE	HEMERODROMIA
DIPEPHNOT		4	2	DIPTERA	EPHYDRIDAE	NOTOPHILA
DIPHELPAL		4	2	DIPTERA	HELEIDAE	PALPOMYIA
DIPMUSLIM		3	2	DIPTERA	MUSCIDAE	LIMNOPHORA
DIPPSY		4	2	DIPTERA	PSYCHODIDAE	
DIPRHAATH		3	2	DIPTERA	RHAGIONIDAE	ATHERIX
DIPSIMSIM		2	2	DIPTERA	SIMULIDAE	SIMULIUM
DIPSTRNEM		4	2	DIPTERA	STRATIOMYIDAE	NEMOTELUS
DIPSTRSTR		4	2	DIPTERA	STRATIOMYIDAE	STRATIOMYS
DIPSYR		5	2	DIPTERA	SYRPHIDAE	
DIPTAB		3	2	DIPTERA	TABANIDAE	
DIPTIPDIC		3	2	DIPTERA	TIPULIDAE	DICRANOTA
DIPTIPHEX		3	2	DIPTERA	TIPULIDAE	HEXATOMA
DIPTIPTIP		4	2	DIPTERA	TIPULIDAE	TIPULA
EPHBAEBAE		4	3	EPHEMEROPTERA	BAETIDAE	BAETIS
EPHBAEDAC		4	3	EPHEMEROPTERA	BAETIDAE	DACTYLOBAETIS
EPHEPHEPH		4	3	EPHEMEROPTERA	EPHEMERELLIDAE	EPHEMERELLA
EPHHEPHEP		2	3	EPHEMEROPTERA	HEPTAGENIIDAE	HEPTAGENIA
EPHHEPRHI		4	3	EPHEMEROPTERA	HEPTAGENIIDAE	RHITHROGENA
EPHHEPCIN		4	3	EPHEMEROPTERA	HEPTAGENIIDAE	CINYGMULA
EPHLEPPAR		4	3	EPHEMEROPTERA	LEPTOPHLEBIIDAE	PARALEPTOPHLEBIA
EPHLEPTRA		4	3	EPHEMEROPTERA	LEPTOPHLEBIIDAE	TRAVERELLA
EPHOLILAC		4	3	EPHEMEROPTERA	OLIGONEURIDAE	LACHLANIA
EPHPOLEPH		2	3	EPHEMEROPTERA	POLYMITARCYIDAE	EPHORON
EPHSIPANA		3	3	EPHEMEROPTERA	SIPHLONURIDAE	ANALETRIS
EPHSIPISO		4	3	EPHEMEROPTERA	SIPHLONURIDAE	ISONYCHIA
EPHTRILEP		1	3	EPHEMEROPTERA	TRICORYTHIDAE	LEPTOHYPHES
EPHTRITRI		1	3	EPHEMEROPTERA	TRICORYTHIDAE	TRICORYTHODES
HEMCOR		1	4	HEMIPTERA	CORIXIDAE	
LEPNOC		1	9	LEPIDOPTERA	NOCTUIDAE	
HEMGER		3	4	HEMIPTERA	GERRIDAE	
HEMNAU		3	4	HEMIPTERA	NAUCORIDAE	
HEMNOT		3	4	HEMIPTERA	NOTONECTIDAE	
HEMVELRHA		4	4	HEMIPTERA	VELIIDAE	RHAGOVELIA
MEGCOR		3	5	MEGALOPTERA	COLYDALIDAE	
NEUMYR		5	9	NEUROPTERA	MYRMELEONTIIDAE	
ODOGOM		3	6	ODONATA	GOMPHIDAE	

(continued)

CODE	LIFE[1] STAGE	FUNCT[2] GRUOP	WEIGHT[3] CURVE	ORDER	FAMILY	GENUS
ODOLES		3	6	ODONATA	LESTIDAE	
ODOLIB		3	6	ODONATA	LIBELLULIDAE	
PLECHLKAT		4	7	PLECOPTERA	CHLOROPERLIDAE	KATHROPERLA
PLECHLPAR		3	7	PLECOPTERA	CHLOROPERLIDAE	PARAPERLA
PLEPEL		2	7	PLECOPTERA	PELTOPERIDAE	
PLEPRLACR		3	7	PLECOPTERA	PERLIDAE	ACRONEURIA
PLEPRLHES		3	7	PLECOPTERA	PERLIDAE	HESPEROPERLA
PLEPERISO		3	7	PLECOPTERA	PERLODIDAE	ISOGENUS
PLETAETAE		2	7	PLECOPTERA	TAENIOPTERYGIDAE	TAENIOPTERYX
TRIBRABRA		4	8	TRICHOPTERA	BRACHYCENTRIDAE	BRACHYCENTRUS
TRIHYDHYD		4	8	TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE
TRIHDRHYD		1	8	TRICHOPTERA	HYDROPTILIDAE	HYDROPTILA
TRIHDRMAY		1	8	TRICHOPTERA	HYDROPTILIDAE	MAYATRICHIA
TRILEPTRI		1	8	TRICHOPTERA	LEPTOCERIDAE	TRIAENODES
TRILIMLIM		4	8	TRICHOPTERA	LIMNEPHILIDAE	LIMNEPHILUS

Other Invertebrates

CODE	LIFE[1] STAGE	FUNCT[2] GROUP	WEIGHT[3] CURVE	CLASSIFICATION
ANNOLI		4	9	ANNELIDA OLIGOCHAETA
MOLGAS		4	9	MOLLUSCA GASTROPODA
NEM		4	9	NEMATODA
TER		5	10	TERRESTRIAL INVERTEBRATE
ARAHYD		3	9	ARACHNOIDEA HYDRACARINA

[1]Key to Life Stages
(blank)=all aquatic life stages
LA = larva
NY = nymph
PU = pupa
AD = adult

[2]Key to Functional Group
1 = Herbivore
2 = Detritivore
3 = Predator
4 = Omnivore
5 = Terrestrial

[3]Key to Wt Curves: biomass(mg)=a*(length(mm))^b

Wt Curve #	a	b
1	.1528	2.18
2	.0054	2.43
3	.0066	2.88
4	.0314	2.40
5	.0029	2.75
6	.0140	2.78
7	.0023	3.39
8	.0019	3.12
9	.0190	2.46
10	.0300	2.62

[1]key to Life Stages
(blank)=all aquatic life stages

LA = larva
NY = nymph
PU = pupa
AD = adult
*IS = instar shuck
*EX = exuvia
*CA = caddis fly larval case

[2]Key to Functional Group

1 = Herbivore
2 = Detritivore
3 = Predator
4 = Omnivore
5 = Terrestrial

[3]Key to Wt Curves: biomass(mg)=a*(length(mm))^b

Wt. Curve #	a	b
1	.1528	2.18
2	.0054	2.43
3	.0066	2.88
4	.0314	2.40
5	.0029	2.75
6	.0140	2.78
7	.0023	3.39
8	.0019	3.12
9	.0190	2.46
10	.0300	2.62

* not considered to be live invertebrates

Appendix 8.A.12

Periphyton Codes

Code	Phylum	Genus
BAC-ACHN	Bacillariophyceae*	Achnanthes
BAC-COCC	Bacillariophyceae*	Cocconeis
BAC-CYCL	Bacillariophyceae*	Cyclotella
BAC-CYMB	Bacillariophyceae*	Cymbella
BAC-DIAT	Bacillariophyceae*	Diatoma
BAC-EPIT	Bacillariophyceae*	Epithemia
BAC-FRAG	Bacillariophyceae*	Fragillaria
BAC-GOMP	Bacillariophyceae*	Gomphonema
BAC-GYRO	Bacillariophyceae*	Cyrosigma
BAC-MAST	Bacillariophyceae*	Mastogloia
BAC-NAVI	Bacillariophyceae*	Navicula
BAC-NITZ	Bacillariophyceae*	Nitzchia
BAC-RHOI	Bacillariophyceae*	Rhoicosphenia
BAC-SURI	Bacillariophyceae*	Surirella
CHL-CLAD	Chlorophyta	Cladophora
CHL-FRIT	Chlorophyta	Fritschiella
CHL-OEDO	Chlorophyta	Oedogonium
CHL-SCEN	Chlorophyta	Scenedesmus
CHL-ULOT	Chlorophyta	Ulothrix
CHL-ZYGN	Chlorophyta	Zygnema
CYA-APHA	Cyanophyta	Aphanothece
CYA-CHRO	Cyanophyta	Chroococcus
CYA-NOST	Cyanophyta	Nostoc
CYA-OSCI	Cyanophyta	Oscillatoria
CYA-RIVU	Cyanophyta	Rivuolaria

* This is a sub-phylum

Appendix 8.A.13

Code of Substrate at Survey Location

code	name	description
BR	bedrock	solid, unbroken rock
BO	boulder	broken rock, >10 cm diameter
CO	cobble	5-10 cm diameter
RU	rubble	1-5 cm diameter
GR	gravel	.5-1.0 cm diameter
SA	sand	.1-.5 cm diameter
SI	silt	.01-.1 cm diameter
CL	clay	<.01 cm in diameter, compacted

Appendix 8.A.14

Dry Weight of Sediment Size Fractions (g)
for April 1981 to October 1982,
size fractions are:

>12.5 mm
<12.5 mm and >4.0 mm
<4.0 mm and >.5 mm
<.5 mm and >.25 mm
<.25 mm

for November 1982 to date,
size fractions are:

>12.5 mm
<12.5 mm and >4.0 mm
<4.0 mm and >2.0 mm
<2.0 mm and >.5 mm
<.5 mm and >.25 mm
<.25 mm and >.125 mm
<.125 mm and >.063 mm
<.063 mm

3. WATER QUALITY PARAMETER FILE AS OF: 02/03/83 PAGE: 1

CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
00003	DEPTH	OF	SAMPLE	(FT FM	SUR-	FACE)	0	R
00004	STREAM	WIDTH	(FEET)				0	R
00008	LAB	ACCOUNT	NUMBER				0	
00009	X-SECT.	LOCATN.	FT. FM.	LT. BNK	LOOKING	DNSTRM.	0	
00010	WATER	TEMPER-	ATURE	(DEG C)			1	
00020	AIR	TEMPER-	ATURE	(DEG C)			1	
00025	BARO-	METRIC	PRES-	SURE	(mm of	Hg)	0	
00027	COLLEC-	TING	AGENCY	CODE *			0	
00028	ANALY-	ZING	AGENCY	CODE *			0	
00029	PROJECT	NUMBER					0	
00042	ALTI-	TUDE,	FT ABV	MSL			0	
00045	PRECIP-	ITATION	ACCUMU-	LATED	(IN)		2	
00046	PRECIP-	ITATION	TOTAL,	(INCHES	/WEEK)		2	
00049	SURFACE	AREA	(MI2)				0	
00050	EVAP-	ORATION	TOTAL	(INCHES	/ DAY)		2	
00055	STREAM	VELOCI-	TY	MEAN	(FPS)		2	
00056	STREAM	AREA	(FT2)				0	R
00058	YIELD	OF	WELL	(GPM)			0	R
00060	MEAN	DAILY	STREAM-	FLOW	(CFS)		0	R
00061	STREAM	FLOW,	INSTAN-	TANEOUS	(CFS)		0	R
00062	NUMBER	OF	SEC-	TIONS			0	
00063	NUMBER	OF	SAMPLE	POINTS			0	
00064	STREAM	DEPTH,	MEAN	(FT)			1	
00065	GAGE	HEIGHT,	FEET	ABV	DATUM		2	
00066	GAGE	HEIGHT	CHANGE	(FEET)			2	
00070	TURBI-	DITY,	(JTU)				0	
00076	TURBI-	DITY	(NTU)				0	R
00080	COLOR	(PCU)					0	
00095	SPECI-	FIC	CONDUC-	TANCE	FIELD	(UMHOS)	0	
00197	EVAPOR-	ATION,	ACCUMU-	LATED	(IN)		2	
00300	DIS-	SOLVED	OXYGEN	(MG/L)			1	
00310	OXYGEN	DEMAND	BIOCHEM	5-DAY	(MG/L)		1	
00335	OXYGEN	DEMAND	CHEM	(MG/L)			1	
00340	OXYGEN	DEMAND,	CHEM	(HIGH	LEVEL)	(MG/L)	1	
00349	OXYGEN	DEMAND	BIOCHEM	30-DAY	(MG/L)		1	
00400	PH	FIELD	(UNITS)				1	
00403	PH,	LAB	(UNITS)				1	
00405	CARBON	DIOXIDE	DISS				1	
00410	ALKA-	LINITY,	FIELD	(MG/L	AS	CACO3)	0	

* 80020 = USGS Central Lab (Denver)
* 1028 = USGS

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
00430	ALKA-	LINITY,	CARBON-	ATE (MG	/L AS	CACO3)	0	
00435	ACIDITY	TOTAL	(MG/L	AS	CACO3)		0	
00440	BICAR-	BONATE	(MG/L	AS	HCO3)		0	
00445	CAR-	BONATE	(MG/L	AS	CO3)		0	
00515	DIS-	SOLVED	SOLIDS	RESIDUE	@ 105 C	(MG/L)	0	
00530	SUS-	PENDED	SOLIDS,	RESIDUE	@ 105 C	(MG/L)	0	
00550	OIL AND	GREASE,	TOTAL	(MG/L)			0	
00556	OIL AND	GREASE,	TOTAL	RECOV.	GRAVIM.	(MG/L)	0	
00572	PERI-	PHYTON	BIOMASS	ASH	WEIGHT	(G/M2)	3	
00573	PERI-	PHYTON	BIOMASS	DRY	WEIGHT	(G/M2)	3	
00600	NITRO-	GEN	TOTAL	(AS N)	(MG/L)		0	R
00602	NITRO-	GEN	DISS	(AS N)	(MG/L)		0	R
00605	NITRO-	GEN,	ORGANIC	TOTAL	(AS N)	(MG/L)	0	R
00607	NITRO-	GEN,	ORGANIC	DISS	(AS N)	(MG/L)	0	R
00608	AMMONIA	DISS	(AS N)	(MG/L)			3	
00610	AMMONIA	TOTAL	(AS N)	(MG/L)			3	
00613	NITRITE	DISS	(AS N)	(MG/L)			3	
00615	NITRITE	TOTAL	(AS N)	(MG/L)			3	
00618	NITRATE	DISS	(AS N)	(MG/L)			0	R
00620	NITRATE	TOTAL	(AS N)	(MG/L)			0	R
00623	AMMONIA	+ORGAN.	NITROGN	DISS.	(AS N)	(MG/L)	0	R
00624	AMMONIA	+ORGAN.	NITROGN	SUSP.	(AS N)	(MG/L)	0	R
00625	AMMONIA	+ORGAN.	NITROGN	TOTAL	(AS N)	(MG/L)	0	R
00630	NITRITE	PLUS	NITRATE	TOTAL	(AS N)	(MG/L)	0	R
00631	NITRITE	PLUS	NITRATE	DISS	(AS N)	(MG/L)	0	R
00635	AMMONIA	+ORGAN.	NITROGN	TOTAL	1DETERM	MG/L -N	2	
00650	PHOS-	PHATE	TOTAL	(MG/L	AS	PO4)	0	R
00660	PHOS-	PHATE,	ORTHO,	DISS	AS PO4	(MG/L)	0	R
00665	PHOS-	PHORUS,	TOTAL	(AS P)	(MG/L)		3	
00666	PHOS-	PHORUS	DISS.	(AS P)	(MG/L)		3	
00671	PHOS-	PHORUS,	ORTHO	DISS	(AS P)	(MG/L)	3	
00680	TOTAL	ORGANIC	CARBON	(TOC)	(MG/L)		0	R
00681	DIS-	SOLVED	ORGANIC	CARBON	(DOC)	(MG/L)	0	R
00683	ORGANIC	CARBON	SUSP	TOTAL	(MG/L)		0	R
00685	TOTAL	IN-	ORGANIC	CARBON	(MG/L)		0	R
00689	SUS-	PENDED	ORGANIC	CARBON	(SOC)	(MG/L)	0	R
00696	HYDRO-	PHOBICS	TOTAL	(DOC)	(MG/L)		1	
00697	HYDRO-	PHOBICS	BASES	(DOC)	(MG/L)		1	
00698	HYDRO-	PHOBICS	ACIDS	(DOC)	(MG/L)		1	

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
00699	HYDRO-	PHOBICS	NEUTRAL	(DOC)	(MG/L)		1	
00700	HYDRO-	PHILICS	TOTAL	(DOC)	(MG/L)		1	
00701	HYDRO-	PHILICS	BASES	(DOC)	(MG/L)		1	
00702	HYDRO-	PHILICS	ACIDS	(DOC)	(MG/L)		1	
00703	HYDRO-	PHILICS	NEUTRAL	(DOC)	(MG/L)		1	
00720	CYANIDE	TOTAL	(MG/L	AS CN)			0	R
00740	SULFITE	(MG/L	AS SO3)				0	R
00745	SULFIDE	TOTAL	(MG/L	AS S)			0	R
00746	SULFIDE	DISS	(MG/L	AS S)			0	R
00900	HARD-	NESS	TOTAL	(AS	CACO3)	(MG/L)	0	
00902	HARD-	NESS,	NONCAR.	(AS	CACO3)	(MG/L)	0	
00915	CALCIUM	DISS	(MG/L)				0	R
00925	MAGNE-	SIUM	DISS	(MG/L)			0	R
00930	SODIUM	DISS	(MG/L)				0	R
00931	SODIUM	ADSORP-	TION	RATIO	(SAR)		0	R
00932	PERCENT	SODIUM					0	
00933	SODIUM	PLUS	POTAS-	SIUM,	DISS.	(MG/L)	0	R
00935	POTAS-	SIUM	DISS	(MG/L)			0	R
00940	CHLOR-	IDE	DISS	(MG/L)			0	R
00945	SUL-	FATE	DISS	(MG/L)			0	R
00950	FLUOR-	IDE	DISS	(MG/L)			0	R
00955	SILICA	DISS	(MG/L)				0	R
01000	ARSENIC	DISS	(UG/L)				0	
01001	ARSENIC	SUS-	PENDED	TOTAL	(UG/L)		0	
01002	ARSENIC	TOTAL	(UG/L)				0	
01003	ARSENIC	TOTAL	IN BOT-	TOM MA-	TERIAL	(UG/G)	0	
01005	BARIUM	DISS	(UG/L)				0	
01006	BARIUM	SUSP.	RECOV-	ERABLE	(UG/L)		0	
01007	BARIUM,	TOTAL	(UG/L)				0	
01008	BARIUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)		0	
01009	BARIUM,	TOTAL	RECOV-	ERABLE	(UG/L)		0	R
01010	BERYL-	LIUM	DIS-	OLVED	(UG/L)		0	
01011	BERYL-	LIUM,	SUS-	PENDED	(UG/L)		0	
01012	BERYL-	LIUM,	TOTAL	(UG/L)			0	
01013	BERYL-	LIUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0	
01015	BISMUTH	DISS-	OLVED	(UG/L)			0	
01020	BORON	DISS	(UG/L)				0	
01023	BORON,	TOTAL	IN BOT-	TOM MA-	TERIAL	(UG/G)	0	
01025	CADMIUM	DISS	(UG/L)				0	

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC RNG
01026	CADMIUM	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0
01027	CADMIUM	TOTAL	(UG/L)				0
01028	CADMIUM	TOTAL	IN BOT-	TOM MAT	(UG/G)		0
01029	CHRO-	MIUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0
01030	CHRO-	MIUM	DISS	(UG/L)			0
01031	CHRO-	MIUM,	SUS-	PENDED	RECOV.	(UG/L)	0
01034	CHROM-	IUM,	TOTAL	(UG/L)			0
01035	COBALT	DISS	(UG/L)				0
01036	COBALT,	SUSP.	RECOV-	ERABLE	(UG/L)		0
01037	COBALT,	TOTAL	(UG/L)				0
01038	COBALT,	TOTAL	IN BOT-	TOM MAT	(UG/G)		0
01040	COPPER	DISS	(UG/L)				0
01041	COPPER,	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0
01042	COPPER,	TOTAL	(UG/L)				0
01043	COPPER,	TOTAL	IN BOT-	TOM MA-	TERIAL	(UG/G)	0
01044	IRON,	SUSP.	RECOV-	ERABLE	(UG/L)		0
01045	IRON	TOTAL	(AS FE)	(UG/L)			0
01046	IRON	DISS	(UG/L)				0
01049	LEAD	DISS	(UG/L)				0
01050	LEAD,	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0
01051	LEAD,	TOTAL	(UG/L)				0
01052	LEAD,	TOTAL	IN BOT-	TOM MA-	TERIAL	(UG/G)	0
01053	MANGAN-	ESE,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0
01054	MAN-	GANESE	SUS-	PENDED	RECOV.	(UG/L)	0
01055	MANGAN-	ESE,	TOTAL	(UG/L)			0
01056	MAN-	GANESE	DISS	(UG/L)			0
01060	MOLYB-	DENUM	DISS	(UG/L)			0
01061	MOLYB-	DENUM,	SUS-	PENDED	(UG/L)		0
01062	MOLYB-	DENUM,	TOTAL	(UG/L)			0
01063	MOLYB-	DENUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0
01065	NICKEL	DISS	(UG/L)				0
01066	NICKEL,	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0
01067	NICKEL,	TOTAL	(UG/L)				0
01068	NICKEL,	TOTAL	IN BOT-	TOM MAT	(UG/G)		0
01075	SILVER	DISS	(UG/L)				0
01076	SILVER,	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0
01077	SILVER,	TOTAL	(UG/L)				0
01078	SILVER,	RECOV.	FM	BOTTOM	MAT	(UG/G)	0
01080	STRON-	TIUM	DISS	(UG/L)			0

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
01085	VANA-	DIUM	DISS	(UG/L)			0	R
01090	ZINC	DISS	(UG/L)				0	
01091	ZINC,	SUS-	PENDED	(UG/L)			0	
01092	ZINC,	TOTAL	(UG/L)				0	
01093	ZINC,	TOTAL	IN BOT-	TOM MAT	(UG/G)		0	
01095	ANTI-	MONY,	DISS.	(UG/L)			0	
01100	TIN	DISS	(UG/L)				0	
01105	ALUM-	INUM,	TOTAL	(UG/L)			0	
01106	ALUM-	INUM	DISS	(UG/L)			0	
01107	ALUM-	INUM,	SUS-	PENDED	RECOV.	(UG/L)	0	
01109	ALUMI-	NUM,	RECOV	FM BOT	MAT	(UG/G)	0	
01120	GALLIUM	DISS.	(UG/L)				0	
01125	GER-	MANIUM	DISS	(UG/L)			0	
01130	LITHIUM	DISS	(UG/L)				0	
01131	LITHIUM	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0	
01132	LITHIUM	TOTAL	(UG/L)				0	
01145	SELE-	NIUM	DISS	(UG/L)			0	
01146	SELE-	NIUM,	SUS-	PENDED	TOTAL	(UG/L)	0	
01147	SELEN-	IUM,	TOTAL	(UG/L)			0	
01148	SELEN-	IUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0	
01150	TI-	TANIUM	DISS	(UG/L)			0	
01160	ZIR-	CONIUM	DISS	(UG/L)			0	
01170	IRON,	TOTAL	IN BOT-	TOM MAT	(UG/G)		0	
01515	GROSS	ALPHA	DISS	(PCI/L	AS	U-NAT)	0	R
01516	GROSS	ALPHA,	SUSP.	TOTAL	(PCI/L	U NAT.)	0	R
03515	GROSS	BETA	DISS	(PCI/L	AS	CS-137)	0	R
03516	GROSS	BETA	SUSP	(PCI/L	AS	CS-137)	0	R
09511	RADIUM	226,	DISS.	RADON	METHOD	(PCI/L)	0	R
10001	TOTAL	ANIONS	(MEQ/L)				2	
10002	TOTAL	CATIONS	(MEQ/L)				2	
10003	ANION-	CATION	BALANCE	(PER-	CENT	DIFF.)	2	
22703	URANIUM	NATURAL	DISS.	(UG/L)			0	R
28403	CESIUM	137,	DISS.	(PCI/L)			0	R
31501	TOTAL	COLI-	FORM	M-ENDO	(COL.	/100ML)	0	
31616	FECAL	COLI-	FORM	M-FC	(COL.	/100ML)	0	
31625	FECAL	COLI-	FORM,	MF .7UM	(COL./	100ML)	0	
31673	FECAL	STREP-	TOCOCCI	KF AGAR	(COL.	/100ML)	0	
31679	FECAL	STREP-	TOCOCCI	M-ENTR.	(COL.	/100ML)	0	
32226	CHLORO-	PHYLL B	PERI-	PHYTON,	SPECTR.	(MG/M2)	3	

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
32228	CHLORO-	PHYLL A	PERI-	PHYTON,	SPECTR.	(MG/M2)	3	
32230	CHLORO-	PHYLL A	PHYTO-	PLANK-	TON		2	
32231	CHLORO-	PHYLL B	PHYTO-	PLANK-	TON		2	
32240	TANNIN	AND	LIGNIN	(MG/L)			0	R
32730	PHENOLS	(UG/L)					0	
38260	METHYL.	BLUE	ACTIVE	SUBSTAN	(MBAS)	(MG/L)	0	R
39250	NAPHTH-	ALENES,	POLY-	CHLORI-	NATED	(UG/L)	0	R
39330	ALDRIN	TOTAL	(UG/L)				0	R
39333	ALDRIN	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39340	LINDANE	TOTAL	(UG/L)				0	R
39343	LINDANE	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39350	CHLOR-	DANE	TOTAL	(UG/L)			0	R
39351	CHLOR-	DANE IN	BOTTOM	MATRL.	(UG/KG)		0	R
39360	DDD	TOTAL	(UG/L)				0	R
39363	DDD	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39365	DDE	TOTAL	(UG/L)				0	R
39368	DDE	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39370	DDT	TOTAL	(UG/L)				0	R
39373	DDT	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39380	DIEL-	DRIN	TOTAL	(UG/L)			0	R
39383	DIEL-	DRIN	IN	BOTTOM	MATRL.	(UG/KG)	0	R
39390	ENDRIN	TOTAL	(UG/L)				0	R
39393	ENDRIN	IN	BOTTOM	MATRL.	(UG/KG)		0	R
39400	TOXA-	PHENE	TOTAL	(UG/L)			0	R
39403	TOXA-	PHENE	IN	BOTTOM	MATRL.	(UG/KG)	0	R
39410	HEPTA-	CHLOR	EPOXIDE	TOTAL	(UG/L)		0	R
39412	HEPTA-	CHLOR,	SUS-	PENDED	TOTAL	(UG/L)	0	R
39413	HEPTA-	CHLOR	IN	BOTTOM	MATRL.	(UG/KG)	0	R
39420	HEPTA-	CHLOR	EPOXIDE	TOTAL			0	R
39423	HEPTA-	CHLOR	EPOXIDE	IN BOT.	MATRL.	(UG/KG)	0	R
39516	PCB	TOTAL	(UG/L)				0	R
39519	PCB	IN	BOTTOM	MATRL.	(UG/KG)		0	
39730	2,4-D	TOTAL	(UG/L)				0	R
39731	2,4-D	IN	BOTTOM	MATRL.	(UG/KG)		0	
39740	2,4,5-T	TOTAL	(UG/L)				0	R
39741	2,4,5-T	IN	BOTTOM	MATRL.	(UG/KG)		0	
39760	SILVEX	TOTAL	(UG/L)				0	R
39761	SILVEX	IN	BOTTOM	MATRL.	(UG/KG)		0	
70300	TOTAL	DISS	SOLIDS	@180 C	(TDS)	(MG/L)	0	

VTN WATER QUALITY PARAMETER FILE AS OF: 02/03/83 PAGE: 7

CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
70301	TOTAL	DISS	SOLIDS	(SUM)	(MG/L)		0	
70302	TOTAL	DISS	SOLIDS	(TONS /	DAY)		0	R
70303	TOTAL	DISS	SOLIDS	(TONS /	AC-FT)		0	R
70337	SUSP	SED	FALL	DIAM	% FINER	.002 MM	0	
70338	SUSP	SED	FALL	DIAM	% FINER	.004 MM	0	
70340	SUSP	SED	FALL	DIAM	% FINER	.016 MM	0	
70341	SUSP	SED	FALL	DIAM	% FINER	.031 MM	0	
70342	SUSP	SED	FALL	DIAM	% FINER	.062 MM	0	
70343	SUSP	SED	FALL	DIAM	% FINER	.125 MM	0	
70344	SUSP	SED	FALL	DIAM	% FINER	.250 MM	0	
70345	SUSP	SED	FALL	DIAM	% FINER	.500 MM	0	
70346	SUSP	SED	FALL	DIAM	% FINER	1.00 MM	0	
70347	SUSP	SED	FALL	DIAM	% FINER	2.00 MM	0	
70507	PHOSPH-	ORUS,	ORTHO,	TOTAL	(MG/L)		0	R
70950	BIOMASS	CHLORO-	PHYLL	RATIO,	PERIPH.	(UNITS)	2	
70953	CHLORO-	PHYLL-A	PHYTO-	PLANKTN	CHR-FLR	(UG/L)	0	R
70954	CHLORO-	PHYLL-B	PHYTO-	PLANKTN	CHR-FLR	(UG/L)	0	R
70955	CHLORO-	PHYLL-A	PERI-	PHYTON	CHR-SPE	(MG/M2)	3	
70956	CHLORO-	PHYLL-B	PERI-	PHYTON,	CHR-SPE	(MG/M2)	3	
71825	ACIDITY	TOTAL,	HEATED	(MG/L	AS H)		0	R
71830	HYDROX-	IDE	ION	(MG/L	AS OH)		0	
71846	AMMONIA	DISS	AS NH4	(MG/L)			0	R
71851	NITRATE	DISS	AS NO3	(MG/L)			0	R
71856	NITRITE	DISS	AS NO2	(MG/L)			0	R
71865	IODIDE,	DISS.	(MG/L)				0	R
71870	BROMIDE	DISS	(MG/L)				0	R
71886	PHOS-	PHORUS	TOTAL	(AS	PO4)	(MG/L)	0	R
71887	NITRO-	GEN,	TOTAL	(AS	NO3)	(MG/L)	0	R
71890	MERCURY	DISS	(UG/L)				0	R
71895	MERCURY	SUS-	PENDED	RECOV-	ERABLE	(UG/L)	0	R
71900	MERCURY	TOTAL	(UG/L)				0	R
71921	MERCURY	TOTAL	IN BOT-	TOM MAT	(UG/G)		0	R
71922	CHROM-	IUM,	TOTAL	IN BOT-	TOM MAT	(UG/G)	0	R
71923	IRON,	RECOV	FM	BOTTOM	MAT	(UG/G)	0	R
72000	ELEVA-	TION	OF LAND	SURFACE	DATUM	(FEET)	1	
72001	DEPTH	OF	HOLE,	TOTAL	(FEET)		0	R
72005	SAMPLE	SOURCE	CODE *				0	
72006	SAMP-	LING	CONDI-	TION	CODE *		2	
72008	DEPTH	OF	WELL	(FEET)			0	R

* 40 = Special
* 0.01 = Dry Hole
4.00 = Flowing

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CODE	LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	LINE 6	DEC	RNG
72019	WATER	LEVEL	(FEET	BELOW	LSD)		2	
72020	ELEVA-	TION OF	STATIC	WATER	LEVEL	(FEET)	2	
80010	URANIUM	DISS.	DIRECT	FLUORO-	METRIC	(PCI/L)	0	R
80020	URANIUM	DISS.	EXTRACT	FLUORO-	METRIC	(UG/L)	0	R
80030	GROSS	ALPHA	DISS	(UG/L	AS	U-NAT)	0	R
80040	GROSS	ALPHA	SUSP	(UG/L	AS	U-NAT)	0	R
80050	GROSS	BETA	DISS	(PC/L	AS SR90	/Y90)	0	R
80060	GROSS	BETA	SUSP	(PC/L	AS SR90	/Y90)	0	R
80154	SEDI-	MENT,	SUS-	PENDED	(MG/L)		0	
80155	SUSP	SEDI-	MENT	DIS-	CHARGE	(T/DAY)	0	R
80164	BED	MATRL.	SIEVE	DIAM.	% <.062	MM	1	
80165	BED	MATRL.	SIEVE	DIAM.	% <.125	MM	1	
80166	BED	MATRL.	SIEVE	DIAM.	% < .25	MM	1	
80167	BED	MATRL.	SIEVE	DIAM.	% < .50	MM	1	
80168	BED	MATRL.	SIEVE	DIAM.	% < 1.0	MM	1	
80169	BED	MATRL.	SIEVE	DIAM.	% < 2.0	MM	1	
80170	BED	MATRL.	SIEVE	DIAM.	% < 4.0	MM	1	
80171	BED	MATRL.	SIEVE	DIAM.	% < 8.0	MM	1	
80172	BED	MATRL.	SIEVE	DIAM.	% < 16	MM	1	
80173	BED	MATRL.	SIEVE	DIAM.	% < 32	MM	1	
80174	BED	MATRL.	SIEVE	DIAM.	% < 64	MM	1	
81024	DRAIN-	AGE	AREA	(MI2)			0	R
82068	POTAS-	SIUM 40	DISS	(PCI/L)			0	R
85209	ALGAL	GROWTH	POTEN-	TIAL,	USGS	(MG/L)	0	R
90095	SPECI-	FIC	CONDUC-	TANCE	LAB,	UMHS@25	0	
90400	PH	LAB,	(UNITS)				1	
90410	ALKALI-	NITY,	LAB	(MG/L	AS	CACO3)	0	
95902	NONCARB	HARD-	NESS	LAB	(MG/L	CACO3)	0	R

Appendix 8.A.16

Status, Condition, and Fate of Active Raptor Nests

Inactive Nests

G = good condition

F = fair condition

P = poor condition

N = nest not checked

O = obsolete (nest has disappeared)

? = condition unknown

NA = not applicable (as for owl nests)

Active Nests

GE = Golden Eagle

RT = Red-tailed Hawk

PF = Prairie Falcon

NH = Northern Harrier

CH = Cooper's Hawk

SS = Sharp-shinned Hawk

GH = Great Horned Owl

LE = Long-eared Owl

Age of Parents

AA = adult-adult

AJ = adult-juvenile

JJ = juvenile-juvenile

Number of Young Produced in Successful Nest

= number of young produced

S = nest successful, number of young uncertain

F = nest failed

? = fate of nest unknown

Date of Hatching

month and day (MDD)

Appendix 8.A.17

Medium Codes

code	medium
0	not determined
A	artificial
B	solids (street sweepings, etc.)
C	animal tissue
D	plant tissue
E	core material
F	interstitial water
G	soil
H	bottom material
J	sludge
K	soil moisture
1	suspended sediment
2	leachate
3	dry deposition
4	landfill effluent
5	elutriation
6	ground water
7	wet deposition
8	bulk deposition
9	surface water

Appendix 8.A.18

Analysis Status Codes

code	analysis status
A	not determined
H	initial entry
1	retrieved, in review
3	data in temporary hold status
7	reviewed, approved for transfer to EPA STORET
9	proprietary data

Appendix 8.A.19

Hydrologic Event Codes

code	hydrologic event
A	spring breakup
B	under ice cover
C	glacial lake outbreak
D	mudflow
E	tidal action
H	dambreak
1	drought
2	spill
3	regulated flow
4	snowmelt
5	earthquake
6	hurricane
7	flood
8	volcanic action
9	routine sample

Appendix 8.A.20

Hydrologic Condition Codes

Code	Hydrologic Condition
A	not determined
4	stable, low stage
5	falling stage
6	stable, high stage
7	peak stage
8	rising stage
9	stable, normal stage

Appendix 8.A.21

Codes for Substances Analyzed for Metal Concentrations

PREC	precipitate
CLAD	Cladophora
DETR	detritus
MACR	macroinvertebrates
PERI	periphyton
ALGA	algae
DRAG	dragon flies
STON	stoneflies
BUGS	macroinvertebrates
FLAN	flannelmouth sucker
GILA	chub species
BLUE	bluehead sucker
DACE	speckled dace
CARP	carp
REDS	red shiner
PLEC	Plecoptera
TRIC	Trichoptera
EPHL	Ephemeroptera larvae
DIMA	diatom matrix

Codes for Fish Species and Tissues

BH	bluehead sucker
GI	chub species
RT	roundtail chub
FB	flannelmouth sucker x bluehead sucker
SK	skin
GA	gastro-intestinal tract
BO	bone
MU	muscle
GC	gut contents
FT	fat
LV	liver
KD	kidney
OV	ovaries

Fish species and tissue codes combine to specify tissue analyzed.
For example: BHBO = bluehead sucker bone tissue

Appendix 8.A.22

Unit Codes for Aerovironment

Unit Code	Unit
1	Kilometers/hour
2	Meters/second
3	Miles/hour
4	Knots
5	Parts per million
6	Parts per hundred million
7	Part per billion
8	Micrograms/cubic meter
9	Grams
10	Ounces
11	Degrees Farenheit
12	Degrees Celsius
13	Degrees Kelvin
14	Inches
15	Centimeter
16	Millibars
17	In of HG
18	MM of HG
19	Feet
20	Kilometers
21	Miles
22	Degrees
23	10^{-4}/M
24	COH/1000ft
25	Langley
26	Micror/hr
27	Percent
28	Standard cubic feet/min
29	DBA (sound level)
30	Milligrams per cubic meter
31	Hundredths of degree F.
32	Hundredths of inches
33	Meters
34	(Cal/cm**2/min)*100
35	Volt AC
36	0=stable, 1=unstable
37	Langleys/minute
38	(in of HG)*100

Appendix 8.B

This appendix contains documentation for the program LIBRARY. The program was written and developed on USU's VAX-11 computer system. It was written in FORTRAN-77.

A sample run of the program is shown in Figure 8.B-1 and samples of the input and output files are shown in Figures 8.B-2 and 8.B-3, respectively. A complete listing of the FORTRAN-77 code is contained in Figure 8.B-4.

```
$ RUN LIBRARY
Enter Organizational Code--AVI, BRI, ERI, NPI, or VTN
AVI
Enter Code of Specific Data Type
(see instruction manual for list of codes)
1
Do You Want All Site Locations?  Y or N
Y
Do You Want All Dates? Y or N
Y
Do You Want To Do Another Search? Y or N
Y
Enter Organizational Code--AVI, BRI, ERI, NPI, or VTN
AVI
Enter Code of Specific Data Type
(see instruction manual for list of codes)
2
Do You Want All Site Locations?  Y or N
N
Enter Number of Locations
2
Enter            2 Location Codes, One Per Line, Max. of 30
A3
A6
Do You Want All Dates? Y or N
N
Enter Initial Search Date in Form YYMMDD
800101
Enter Final Search Date in Form YYMMDD
800630
Do You Want To Do Another Search? Y or N
N
Output in file LIST.DAT
End of LIBRARY
$
```

Figure 8.B-1. Sample run of program LIBRARY. User supplied inputs are underlined. Data type codes are in Appendix 8.A.

Input Values:

Organization: AVI Data-type Code: 1
Location(s): A3 A6
Starting Date: 790101 Ending Date: 800630

Location Code	Initial Date	Final Date	Frequency Code	Disk or Tape	Tape No.	File Name
A6	790101	791231	1	T	1	AIRQUAL.79
A6	800101	801231	1	T	1	AIRQUAL.80

Figure 8.B-2. Sample of output file, LIST.DAT, from program LIBRARY.

```
04 21 06 0401   760602 761012 D 04   RT76.VLD
04 22 06 0401   760602 761012 D 04   RT76.VLD
04 23 06 0401   760602 761012 D 04   RT76.VLD
04 24 06 0401   760602 761012 D 04   RT76.VLD
04 16 06 0402   760616 761012 D 04   RT76.VLD
04 17 06 0402   760616 761012 D 04   RT76.VLD
04 18 06 0402   760616 761012 D 04   RT76.VLD
04 19 06 0402   760616 761012 D 04   RT76.VLD
04 20 06 0402   760616 761012 D 04   RT76.VLD
04 21 06 0402   760616 761012 D 04   RT76.VLD
04 22 06 0402   760616 761012 D 04   RT76.VLD
04 23 06 0402   760616 761012 D 04   RT76.VLD
04 24 06 0402   760616 761012 D 04   RT76.VLD
04 15 06 0101   770208 770808 D 04   RT77.VLD
```

Figure 8.B-3. Portion of input file (PARMDATES.BRI) from LIBRARY.

```
00100   C*********************************************************************
00200   C
00300   C
00400   C            * * * * *  PROGRAM LIBRARY * * * * *
00500   C
00600   C                        Written by Ron Ryel
00700   C                   Ecosystem Research Institute
00800   C                          Logan, Utah
00900   C
01000   C*********************************************************************
01100   C
01200   C                        LIST OF VARIABLES
01300   C
01400   C       User supplied input variables:
01500   C
01600   C          YN      = yes or no response
01700   C          ORG     = Consultant code
01800   C          NC      = Code identifying specific parameter type
01900   C          NL      = Number of sample locations of interest
02000   C          DAYI    = Initial date of sample period of interest
02100   C          DAYF    = Final date of sample period of interest
02200   C          LC(I)   = Location code of sample site I
02300   C
02400   C       Input variables from PARMDATES data files:
02500   C
02600   C          NCD     = Code number of organization
02700   C          NSD     = Code identifying specific data type
02800   C          NCF     = Code representing frequency of sample collection
02900   C          LOC     = Code identifying sample location
03000   C          ISD     = Initial sampling date
03100   C          FSD     = Final sampling date
03200   C          D       = On active disk storage
03300   C          TN      = Tape number of original tape
03400   C          FN      = File name
03500   C
03600   C       Other variables used in program:
03700   C
03800   C          ORGC(i)= Code for organization i
03900   C          NNN     = Line number counter for PARMDATES file
04000   C
04100   C*********************************************************************
04200   C*********************************************************************
04300   C
04400   C
04500   C
04600           CHARACTER ORGC(5)*3,ORG*3,YN*1,D*1,TN*4,FN*13,NAME*20,NC*2,NSD*2
04700           CHARACTER*6 LOC,ISD,ESD,DAYI,DAYF,LC(30)
04800           LOGICAL A1,A2,A3
04900           DATA ORGC/'AVI','VTN','NPI','BRI','ERI'/
05000           DATA A1,A2,A3/.TRUE.,.TRUE.,.TRUE./
```

Figure 8.B-4. Listing of the source version of the program LIBRARY.

```
05100   C=====================================================================
05200   C
05300   C === This section prompts the user for input information.
05400   C
05500   C.....................................................................
05600     11    TYPE *,'Enter Organizational Code--AVI, BRI, ERI, NPI, or VTN'
05700           READ(5,500) ORG
05800           DO I=1,5
05900           IF(ORG.EQ.ORGC(I)) GO TO 10
06000           ENDDO
06100           TYPE *,ORG,' is not correct code.'
06200           GO TO 11
06300   C>>>>>>>  The appropriate input file is opened
06400     10    NAME='PARMDATES.'//ORG
06500           OPEN(1,STATUS='OLD',FILE=NAME)
06600   C>>>>>>>
06700           NOC=I
06800           DAYI='all'
06900           DAYF='all'
07000           TYPE *,'Enter Code of Specific Data Type'
07100           TYPE *,'(see instruction manual for list of codes)'
07200           READ(5,'(A)') NC
07300     15    TYPE *,'Do You Want All Site Locations?  Y or N'
07400           READ(5,500) YN
07500           IF(YN.EQ.'N'.OR.YN.EQ.'n'.OR.YN.EQ.'Y'.OR.YN.EQ.'y') THEN
07600           IF(YN.NE.'Y'.AND.YN.NE.'y') THEN
07700           A1=.FALSE.
07800     19    TYPE *,'Enter Number of Locations'
07900           READ(5,'(I4)',ERR=95) NL
08000           TYPE *,'Enter',NL,' Location Codes, One Per Line, Max. of 30'
08100           READ(5,500) (LC(I),I=1,NL)
08200           ENDIF
08300           ELSE
08400           WRITE(6,*) 'Incorrect response -- Try again'
08500           GO TO 15
08600           ENDIF
08700     16    TYPE *,'Do You Want All Dates? Y or N'
08800           READ(5,500) YN
08900           IF(YN.EQ.'N'.OR.YN.EQ.'n'.OR.YN.EQ.'Y'.OR.YN.EQ.'y') THEN
09000           IF(YN.NE.'Y'.AND.YN.NE.'y') THEN
09100           A2=.FALSE.
09200     17    TYPE *,'Enter Initial Search Date in Form YYMMDD'
09300           READ(5,500,ERR=97) DAYI
09400           IF(DAYI(1:1).LT.'1'.OR.DAYI(1:1).GT.'9') THEN
09500           WRITE(6,*) 'Incorrect response -- Try again'
09600           GO TO 17
09700           ENDIF
09800     18    TYPE *,'Enter Final Search Date in Form YYMMDD'
09900           READ(5,500,ERR=96) DAYF
10000           IF(DAYF(1:1).LT.'1'.OR.DAYF(1:1).GT.'9') THEN
```

```
10100          WRITE(6,*) 'Incorrect response -- Try again'
10200          GO TO 18
10300          ENDIF
10400          ENDIF
10500          ELSE
10600          WRITE(6,*) 'Incorrect response -- Try again'
10700          GO TO 16
10800          ENDIF
10900   C=====================================================================
11000   C
11100   C === The output file is opened and the header information for the
11200   C     output is written in the file (LIST.DAT)
11300   C
11400   C.....................................................................
11500          OPEN(2,STATUS='NEW',FILE='LIST.DAT')
11600          WRITE(2,200) ORGC(NOC),NC
11700          IF(A1) THEN
11800             WRITE(2,*) 'Data from all locations'
11900          ELSE
12000             WRITE(2,202)(LC(I),I=1,NL)
12100          ENDIF
12200          IF(A2) THEN
12300             WRITE(2,*) 'Data from all dates'
12400          ELSE
12500             WRITE(2,203) DAYI,DAYF
12600          ENDIF
12700          WRITE(2,204)
12800          NNN=0
12900   C=====================================================================
13000   C
13100   C === The PARMDATE input file is read line by line and the appropriate
13200   C     sample information is extracted and printed in the output file
13300   C     LIST.DAT
13400   C
13500   C.....................................................................
13600     12   READ(1,100,END=99,ERR=98) NGD,NSD,NCF,LOC,ISD,ESD,D,TN,FN
13700          NNN=NNN+1
13800          IF(NGD.NE.NOC) GO TO 12
13900   C>>>>>>>  Checking to see if record is appropriate
14000          IF(NC(1:1).EQ.' '.OR.NC(1:1).EQ.'0') THEN
14100            IF(NSD(1:1).NE.' '.AND.NSD(1:1).NE.'0') GO TO 12
14200            IF(NSD(2:2).NE.NC(2:2)) GO TO 12
14300          ELSE IF(NC(2:2).EQ.' ') THEN
14400            IF(NSD(1:1).NE.' '.AND.NSD(1:1).NE.'0') GO TO 12
14500            IF(NSD(2:2).NE.NC(1:1)) GO TO 12
14600          ELSE
14700            IF(NSD.NE.NC) GO TO 12
14800          ENDIF
14900          IF(.NOT.A1) THEN
15000          DO I=1,NL
```

```
15100          IF(LOC.EQ.LC(I)) GO TO 13
15200          ENDDO
15300          GO TO 12
15400    13    ENDIF
15500          IF(.NOT.A2) THEN
15600          IF(DAYF.GE.ISD.AND.DAYF.LE.ESD) GO TO 14
15700          IF(DAYI.GE.ISD.AND.DAYI.LE.ESD) GO TO 14
15800          GO TO 12
15900          ENDIF
16000  C>>>>>>>
16100    14    WRITE(2,201) LOC,ISD,ESD,NCF,D,TN,FN
16200          A3=.FALSE.
16300          GO TO 12
16400    99    IF(A3) WRITE(2,*) 'No Data as Specified'
16500  C=====================================================================
16600  C
16700  C === The user is asked if another parameter search is desired in the
16800  C     same PARMDATES file
16900  C
17000  C.....................................................................
17100          TYPE *,'Do You Want To Do Another Search? Y or N'
17200          READ(5,500) YN
17300          IF(YN.EQ.'Y'.OR.YN.EQ.'y') THEN
17400          REWIND 1
17500          GO TO 11
17600          ENDIF
17700  C=====================================================================
17800  C
17900  C === Program is terminated
18000  C
18100  C.....................................................................
18200          WRITE(6,*) 'Output in file LIST.DAT'
18300          STOP 'End of LIBRARY'
18400  C=====================================================================
18500  C
18600  C === These are responses to various input error conditions
18700  C
18800  C.....................................................................
18900    98    NNN=NNN+1
19000          WRITE(6,600) NNN,NAME
19100          GO TO 12
19200    95    WRITE(6,*) 'Incorrect response -- Try again'
19300          GO TO 19
19400    96    WRITE(6,*) 'Incorrect response -- Try again'
19500          GO TO 18
19600    97    WRITE(6,*) 'Incorrect response -- Try again'
19700          GO TO 17
19800  C=====================================================================
19900  C
20000  C === Read and write formats
```

```
C
C.....................................................................
  100   FORMAT(I2,X,A,X,I2,X,6(A,X))
  200   FORMAT('0'///' Input Values: '/'0 Organization: ',A,
     1  '    Data-type Code:',2X,A)
  202   FORMAT('  Location(s): ',9(X,A))
  203   FORMAT('  Starting Date: ',A,'   Ending Date: ',A)
  201   FORMAT(' ',X,A,3X,A,4X,A,I7,8X,A,5X,A,3X,A)
  204   FORMAT('0Location  Initial   Final  Frequency  Disk or  Tape'/
     1          '   Code    Date     Date     Code      Tape     No.   F
     1ile Name'/' ',63('-'))
  500   FORMAT(A)
  600   FORMAT(' *** Format error in line number',I6,' of ',A)
        END
```

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